"The Practitioner" Series

DISEASES OF THE HEART AND CIRCULATION

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To

SIR JOHN PARKINSON

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PREFACE

THE rapid advance in cardiology during the first half of the twentieth century may be fairly ascribed to the introduction of new techniques. Riva Roca's mercurial sphygmomanometer (1896), Mackenzie's polygraph (1902), Einthoven's string galvanometer (1903), and Röntgen's beam (1895) opened the new era, and in the hands of men such as Sir Clifford Allbutt, Sir James Mackenzie, Sir Thomas Lewis and Sir John Parkinson respectively, soon solved or clarified innumerable problems. Further impetus resulted from the elaboration and perfection of these methods, particularly from unipolar lead electrocardiography and angiocardiography, for which we have to thank Frank Wilson (1932 et seq.), Castellanus (1937), and Robb and Steinberg (1938) More recently still Forsmann's courageous use of the cardiac catheter on himself (1929) led to its clinical application on a wide scale, particularly owing to the efforts of Cournand (1941) in the U S.A. and of McMichael and Sharpey-Schafer (1944) in England Thus electrocardiography, cardiac radiology, and the physiology of the heart and circulation have advanced side by side At the same time the surgeons have invaded what was once forbidden territory and are rapidly turning miraculous operations on the heart into the commonplace. Amongst the many pioneers who have helped to develop safe routine cardiac surgery must be included Claud S. Beck, E D. Churchill, Lawrence O'Shaughnessy, R. E. Gross, Alfred Blalock, C. Crafoord, and R. C Brock, although so many distinguished surgeons have played their part that it may seem invidious to mention names It is, perhaps, not really a coincidence that more precise methods of diagnosis became available just when surgery demanded them.

The more conservative physicians may have witnessed these and many other less important technical developments with some misgiving, but relatively few have expressed reactionary views. Yet there is already plenty *of evidence to show that we are in danger of losing our clinical heritage* and of pinning too much faith in figures thrown up by machines Medicine must suffer if this tendency is not checked.

In presenting this book I have attempted to maintain a proper balance between man and his instruments, between experienced opinion and statistics, between traditional views and the heterodox, between bed-side medicine and special tests, between the practical and the academic, and so to link the past with the present.

January 1950 PAUL WOOD

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AUTHOR'S NOTE

The method of numbering the figures was adopted so that desirable changes could be made from time to time without upsetting the order of the illustrations in subsequent chapters The number before the decimal point represents the chapter in which the illustration occurs, whilst the number after the decimal point is serial for that chapter Thus, figure 3 15 refers to the fifteenth illustration in chapter 3 From the author's point of view the system proved highly successful, it is hoped that the reader will not find it irksome.

The method of mounting the electrocardiograms has been adopted because it is the only way in which a simple and harmonious design can be made to indicate the approximate position of the leads. The apices of the triangle represent the relative positions of the three conventional limb electrodes: unipolar limb leads (Goldberger's augmented leads are used throughout) and standard leads are placed accordingly Chest leads (V1–V6) are shown horizontally across the centre. In adopting such a convention no theoretical assumptions are necessary; nor have they been made.

In the title of the book the word circulation refers to the general circulation, not to peripheral vascular disease. A chapter on the latter was originally included, but was finally abandoned as separate monographs on the subject appeared in greater profusion.

Anatomy and pathology have been discussed only when clinically relevant.

The arrangements of the contents has been determined chiefly by physiological and etiological considerations, rather than by morbid anatomy. Thus there are no chapters devoted to valve disease as a whole, nor to diseases of the myocardium It is believed that the advantages of such an arrangement outweigh the disadvantages.

Special attention has been paid to the index, so that it serves a dual role It may be used both conventionally and as a guide to differential diagnosis

The book has been written primarily for graduates interested in clinical cardiology, but the needs of students, general practitioners, and specialist physicians in other fields of medicine have been constantly borne in mind. It is not intended for the advanced academic cardiologist or research worker.

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DISEASES OF THE HEART AND CIRCULATION

CHAPTER I

APPROACH TO CARDIOLOGY

HEART disease is by far the most common cause of natural death in civilised communities in the more temperate zones of the world. It is responsible for about one-third of all such deaths and for an annual mortality rate in the general population of about 0.4 per cent Both incidence and mortality curves have been rising steadily for many years, a fact which is not fully explained by ageing populations and by the control of infectious fevers, pulmonary tuberculosis, and pyogenic infections The incidence and mortality rate of cancer, for example, shows no comparable rise. Ischæmic heart disease, particularly, is on the increase

The relative incidence of the various forms of heart disease classified according to etiology is given below

	Per cent
Congenital heart disease	2
Rheumatic heart disease	25
Bacterial endocarditis	2
Syphilitic aortitis	3
Ischæmic heart disease	25
Hypertensive heart disease	30
Pulmonary heart disease	5
Thyrotoxic heart disease	5
Miscellaneous and uncertain	3
	100

HISTORY-TAKING

To take an accurate and relevant history is one of the most difficult and important arts in medicine Sometimes, a complete diagnosis can be made from the history alone, and not infrequently the possibilities can be whittled down to two or three A good history should at least indicate the system involved, or it should point unerringly to some group or groups of diseases A common mistake is the failure to analyse any given symptom sufficiently; in cardiovascular work this applies especially to pain, breathlessness, palpitations, and syncope. The student is usually taught to encourage the patient to tell his story in his own words, and to record them more or less verbatim Yet such an account may be verbose, irrelevant, inaccurate, and misleading It is an axiom that the leading question must be avoided at all cost, yet again, an experienced physician must know that

the ability to put the appropriate leading question at the right moment, and the intelligent interpretation of its reply, are invaluable It is not pretended that leading questions may not lead to false information, if the power of their suggestion is not appreciated by the questioner; and it is agreed that much may be lost by failure to allow the patient freedom and time to express his complaints in his own way, but the average patient will not mention half the available information until he is pressed, and the data freely given must be checked as at the bar For example, in the differential diagnosis between a neural and non-neural somatic lesion, an accurate description of the quality of the pain may determine the issue immediately; yet the majority of patients will volunteer no information concerning the quality of pain, and if asked to describe it will do so inadequately. They may say it is aching or sharp, but fail to enlarge on this, even when urged to do so. In answer to the leading question, "Does it tingle?", however, they may reply at once in the affirmative. It is essential to realise that the matter does not end there that such a positive reply to a leading question demands the most penetrating cross-examination, until the questioner is satisfied that the pain really does tingle, and that the patient is not merely saying so because it seems the easier answer. It is scarcely too much to say that the best history-taker is he who can best interpret the answer to a leading question Appropriate leading questions can only be asked, however, when the proffered history has provided sufficient data upon which to work, and if the physician has sufficient knowledge of the possibilities then entailed. It is this latter factor which makes it easier for the expert than for the student.

CLINICAL EXAMINATION

There are two methods of examining a patient: the first begins at the top of the head and ends with the toes, a method often adopted for the sake of convenience, the second is to examine the various systems of the body, one by one, in logical sequence The procedure recommended here is concerned only with the cardiovascular system, but it is essential, of course, that all other systems be examined.

Inspection While extracting the history the physician should be making a preliminary general inspection He should pay particular attention to the head and neck, looking for goitre and for the eye signs of thyrotoxicosis, for Corrigan's sign, and especially for jugular pulsation He will note the general build and appearance of the patient, his attitude and demeanour, and should form some idea of his character He should observe plethora, pallor, or cyanosis. He may see that respiration is hurried, irregular, shallow, or wheezy; or he may detect the tell-tale sigh of emotional tension

to observe without effort, taking note of them without seeming to do so, and

in such a limited survey may be put on the track of the correct diagnosis, and be forewarned where to look most diligently for further signs

Determining the presence or absence of congestive heart failure. Congestive [illegible] pressure may be assessed by inspecting the cervical veins, and is fully considered in Chapter V. The examiner should not feel guilty if he switches from inspection of the neck to palpation of the liver, to discover whether or not that organ is engorged, nor should he feel embarrassed if he desires to turn from the right hypochondrium to the feet and sacral region in search of œdema; if he be criticised for gymnastics, he may reply that he is more concerned with the logical sequence of his thoughts

The pulse. It is customary to examine the pulse first at the wrist, and to consider it in terms of speed, rhythm, tension, amplitude, and quality, at the same time it is convenient to note the state of the arterial wall Whilst speed and rhythm may be checked by auscultation of the heart, and tension by sphygmomanometry, the quality and amplitude of the pulse wave can only be analysed in peripheral vessels, and are features of great diagnostic importance. Thus an anacrotic or plateau pulse of small volume signifies aortic stenosis; a bisferiens pulse, combined aortic stenosis and incompetence, a water-hammer pulse, vasodilatation, and so on. Attention should next be directed to the other radial artery, thence to the brachials, carotids, femorals, posterior tibials, and finally to the dorsal arteries of the feet. Difficulty in locating the radial artery may be due to its taking an aberrant dorso-lateral course. Weakness on one or other side usually denotes proximal compression, as from aneurysm of the aorta, but a weak left radial pulse may be due to an ectopic origin and aberrant course of the left subclavian artery. Examination of the brachial arteries is particularly fruitful, both with respect to the pulse wave and to the state of the vessel itself, and should never be neglected The carotids may present a thrill or shudder suggesting aortic stenosis, Corrigan's sign indicating aortic incompetence, or kinking from atherosclerosis. Routine palpation of the femorals would insure the immediate recognition of coarctation of the aorta in nearly all cases, diminished and delayed pulsation being characteristic and pathognomonic. The presence of pulsation in the vessels of the feet should always be recorded, if only for subsequent reference. Finally, the colour and temperature of the hands and feet should be noted, if they are warm, an attempt should be made to detect digital throbbing and capillary pulsation The latter is best demonstrated by means of transillumination.

The blood pressure Approximate estimation of the blood pressure by clinical means is not only possible, but should be practised regularly, with experience it is easy to tell whether it is low, normal, or high, and the procedure takes but a moment The physician should stand in front and to the right of the patient, and should compress the right brachial artery with his

right thumb, while feeling the right radial pulse with the fingers of his left hand, the force required to obliterate the pulse represents the systolic blood pressure. The alternative method of placing three fingers on the radial artery, the first to compress the vessel above, the second to feel the pulse, and the third to obliterate the ulnar collateral below, is difficult, cumbersome, and less reliable.

In cardiovascular work, however, the blood pressure should always be measured with a mercurial manometer, or if an aneroid instrument is used, it should be calibrated at frequent intervals against the standard mercurial type The patient must be comfortable, whether lying or sitting, and must have had time to recover from any recent excitement or exertion. The arm should be bared to the shoulder to avoid constriction from clothing and to facilitate proper application of the cuff The latter should be fitted closely and evenly round the arm, so that its lower edge is one inch above the bend of the elbow, and the middle of the rubber bag lies over the brachial artery. Preliminary readings should be taken by palpation· as the cuff is inflated, the point at which pulsation can no longer be felt in the brachial artery represents the systolic blood pressure; as the cuff is deflated, brachial pulsation gradually assumes a water-hammer quality, and then abruptly resumes its normal character, the reading corresponding to this sudden change represents the diastolic blood pressure. Readings obtained on inflation should be checked on deflation, and vice versa When approaching an end-point the pressure must be altered slowly in the cuff. The palpatory method avoids the pitfall of the auscultatory gap, and is uninfluenced by subjective auditory defects; nevertheless, it must be checked by auscultation The stethoscope should be applied lightly and accurately over the brachial artery, just below but not in contact with the cuff The latter is then inflated to a pressure of some 30 mm. Hg above the systolic pressure as found by palpation, and slowly deflated. The accepted systolic blood pressure is the highest level at which successive sounds are heard. As the pressure is further lowered in the cuff, the dull thud of the upper limits is replaced first by a murmur, and then by louder and sharper sounds; the point at which these slapping sounds suddenly become muffled should be taken as the diastolic pressure. When there is vasodilatation, especially when associated with aortic incompetence, sounds may still be heard when the cuff pressure is reduced to zero, but normally they disappear a few mm. Hg below the change-over.

[illegible]

bu [illegible]

un [illegible]

there are ectopic beats, the higher pressure of the beat which follows the ectopic should be ignored. In auricular fibrillation only approximate readings can be obtained, the systolic pressure should be taken at the point where the majority of beats come through, the diastolic where the majority of beats become muffled. As the blood pressure normally varies by a few

mm. Hg with respiration, it may be suitably recorded to the nearest multiple of five.

The above recommendations are freely borrowed from the joint report of the committees appointed by the British Cardiac Society and the American Heart Association for the standardisation of methods of measuring the arterial blood pressure (1939)

The normal systolic blood pressure lies between 95 and 145 mm. Hg Whilst it is true that apparently normal subjects between the ages of 40 and 60 tend to have higher systolic pressures than those between 20 and 40, it is not true to say that a normal blood pressure should be 100 mm Hg plus the age of the patient in years. On the contrary, insurance companies well recognise the value of low figures, and it is probable that the higher average pressures of the middle-aged and elderly are due to atherosclerosis (Lewis, 1938). The normal diastolic blood pressure lies between 60 and 90 mm. Hg The mean pressure approximates to the diastolic plus one-third of the pulse pressure.

A common source of error in blood pressure estimation results from failure to obtain a basal reading; this may be due to impatience, or to lack of recognition of emotional or other physiological factors. Whenever the pressure is found to be raised, the cuff should be left in position so that a second reading may be taken at the end of the examination Casual measurements in healthy young adults who are a little anxious often register 160/90 mm Hg, but if the patient is put at ease, and allowed to rest quietly on a couch, this figure may fall steadily to normal levels It must be thoroughly understood that the maximum normal blood pressure of 145/90 mm Hg is basal. The question of pre-hypertensive levels will be discussed later

Slight disparity between readings taken from each arm is common, especially in atherosclerotic and hypertensive subjects, but the difference rarely exceeds 5 mm Hg (Amsterdam and Amsterdam, 1943) The blood pressure is sometimes taken in the legs with the cuff above the knee and the stethoscope in the popliteal fossa In the average normal individual in the horizontal position, the blood pressure in the legs reads 20 to 40 mm. Hg above that in the arms. This difference is lessened if the body is tilted head-down, and increased if it is tilted head-up The discrepancy appears to depend upon the cuff method of estimating the blood pressure, for it is not found when the blood pressure is measured by means of direct arterial [illegible]

diastolic pressure rises about 5 mm Hg in 48 per cent of normal subjects, drops about 5 mm Hg in 12 per cent, and remains unchanged in 40 per cent (Currens, 1948).

The ocular fundi Before leaving the peripheral vascular system, the ocular fundi should be examined The ophthalmoscope should be used with both eyes open, and with either hand, so that one may hold the instru-

ment with the right hand when examining the patient's right eye, and with the left hand when examining his left eye. There are four features of particular interest to the cardiologist the appearance of the disc, the calibre of the arteries, the presence of hæmorrhages, and the presence of exudates. Details are described on page 423.

EXAMINATION OF THE HEART

Having gleaned as much information as possible from general inspection, from searching for signs of failure, and from examining the peripheral vascular system, one may turn with advantage to the heart itself, and duly inspect, palpate, percuss and auscultate

Inspection The position and character of the cardiac impulse, if visible, and of any other thoracic pulsation, should be noted. In this way, left or right ventricular hypertrophy, gallop rhythm, dilatation of the pulmonary artery, and aortic aneurysm may be detected. Præcordial deformity may be observed, and if due to the heart indicates its enlargement during the period of thoracic growth Depression of the sternum, or other thoracic deformity, should be noted, for it may alter the shape or position of the heart Systolic indrawing of the thoracic wall is not abnormal if it occurs over the right ventricle, and may be seen in the anterior axillary line when there is gross cardiac enlargement, as a sign of adherent pericardium (see page 351) it should be looked for posteriorly over the last two ribs, as described by Broadbent (1895)

Palpation. The apex beat, which is a geographical point, should be determined by locating the exact site of the maximum cardiac impulse. The physician's hand should be placed over the region of the fifth left intercostal space in the nipple line in order to ascertain its approximate position· the middle finger should then be directed vertically over it, and shifted about until the maximum thrust is located This, rather than the lowest left point of such pulsation, is the apex beat Its position should be recorded with reference to the intercostal spaces, to the mid-line, and to the mid-clavicular line It is usually in the fifth intercostal space, 8–9 cm to the left of the mid-line, or just within the mid-clavicular line If it is located beyond these confines, the possibility of displacement from scoliosis, elevation of the diaphragm, or from pulmonary or pleural lesions should be considered before concluding that the heart is enlarged

The character of the cardiac impulse is as important, if not more important, than its position (the apex beat), it should be sensed both with the palm of the hand and with the finger-tip. The qualities of heaving, thrusting, over-action, tapping, and triple rhythm, can only be learned at the bedside

Palpation may next be used to detect the presence of thrills, preferably in forced expiratory apnœa This manœuvre brings the heart and great vessels closer to the chest wall, encourages the lung to retract from its buffering position, and lessens the chance of confusing cardiac with respira-

tory phenomena. The vibration sense of normal individuals varies considerably, but increased perception comes with experience and good technique. Thrills should be timed against carotid pulsation.

Finally, palpation may be employed to detect abnormal pulsations of the great vessels, especially from aneurysm of the ascending aorta or from dilatation of the pulmonary artery.

Percussion. The value of percussing the heart has given rise to much dispute, many modern cardiologists maintaining that its place has been taken by the far more accurate and fertile method of radiography. The older school, however, modestly suggest that it is a useful bedside method, which gives reliable and helpful information if practised diligently, and if its limitations are appreciated. Certainly, if a fluoroscope is available, percussion is pointless; but a fluoroscope may not be available, or the patient may be so ill that only a portable X-ray machine can be used, and the distorted skiagram so obtained is liable to gross misinterpretation. In such cases percussion may be of value, and by constant practice the physician should learn what can, and what cannot, be expected from it.

The approximate position of the left border of the heart may be checked when the apex beat is difficult to locate, and dullness beyond the known or probable confines of the apex beat may sometimes be detected in cases of pericardial effusion.

It is impossible to determine the right border of the heart by percussion, unless there is aneurysmal dilatation of the right auricle. On the other hand, pericardial effusion, even of moderate degree, can often be demonstrated.

It was once customary to speak of relative and absolute cardiac dullness, the latter being the note heard over the area of heart not covered by lung, but it is doubtful whether this distinction can be maintained. Diminution or absence of cardiac dullness, however, is a useful sign of emphysema.

Percussion at the base may be rewarded in pericardial effusion, there being characteristic dullness in the second left interchondral space when the patient lies flat; also in substernal goitre, and in anterior aneurysm of the aorta, when a band of dullness extends laterally from the manubrium sterni.

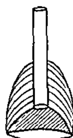
Auscultation. When a man buys a tool for some specific purpose, he usually takes care that it is the best available for the particular job in hand. It is therefore strange that a superstition has grown up within the medical world that the older and more disreputable a stethoscope, the better, that it is not the stethoscope which matters, but the man behind it. This, of course, is nonsense. When a student fails to hear a murmur which is heard easily by another, exchange of stethoscopes quickly leads to mutual understanding. There is another curious tradition, fostered by many who appreciate the value of a good stethoscope, that the chest-piece must be bell-shaped, and that any other type, especially the flat diaphragm (Bowles), is pernicious. This doctrine is as unreasonable as the first, for there is no

doubt that certain high-pitched sounds, especially aortic diastolic murmurs

the Bowles chest-piece should be about 1½ inches; the cup should be shallow and its edge sharp (fig. 1.01 a). Good material for the diaphragm is photographic or X-ray film, washed clean in hot water, and cut to shape. The rubber tubing must be thick, and should fit snugly to the connections The internal calibre of the whole system should be nowhere less than the diameter of the hole in the centre of the chest-piece, which should measure about 5 mm. A good bell stethoscope (fig. 1.01 b) is better for detecting low-pitched sounds, such as soft mitral diastolic murmurs; moreover, its range of sensitivity may be increased by varying the force with which it is applied to the chest wall. Light contact accentuates low-pitched sounds, firm pressure high-pitched sounds. The cup should not be too deep, and its diameter should not be less than one inch.



(a) Bowles



(b) Bell

Fig 1 01—Binaural Stethoscopes

There are two other types of stethoscope which deserve comment. the monaural wooden instrument of by-gone days, and the differential stethoscope (symballophone) The rigid wooden stethoscope is rarely used nowadays, but by combining aural and tactile senses it facilitates the recognition of gallop rhythm. The differential stethoscope is constructed as shown in fig 1 02, and may be used to compare the timing of sounds originating at different sites, and to determine the direction in which a murmur is propagated (Kerr *et al.*, 1937)

Auscultation of the heart can only be learned at the bedside, but the following advice may be helpful to students. The præcordium should be examined all over, not just at areas where individual valve sounds are expected, gallop rhythm, pericardial friction, and certain important murmurs will not then escape notice. It is enough to listen to one thing at a time: thus, when an expert hears a soft elusive mitral diastolic murmur, hitherto overlooked, it is not necessarily because he has better ears or a better stethoscope, but because he has acquired a more selective power of concentration. Basal murmurs and pericardial friction are heard most easily in expiratory apnœa; tricuspid murmurs in inspiratory apnœa; mitral murmurs in the left lateral position, especially after exercise or after the inhalation of amyl nitrite. Heart sounds should be timed against carotid pulsation; if difficulty is experienced due to tachycardia, the heart may be slowed by carotid sinus compression.

The heart valves lie so close together, that a stethoscope placed over them transmits sounds from all, making it difficult to distinguish one from another. Certain favourable areas have come to be recognised, however, at which each valve may be studied selectively. Although such areas represent maximum purity of particular valve sounds, they do not represent maximum intensity Thus, if a valve sound or murmur is faint, it may be inaudible at the site of selection, yet heard clearly elsewhere. Aortic diastolic murmurs, for example, with the possible exception of those associated with

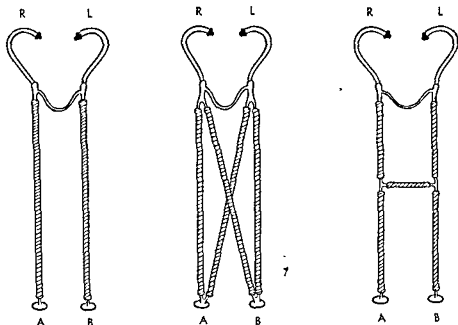


Fig 1 02—The Differential Stethoscope (3 varieties) Sounds travelling from A to B reach the right ear before the left, giving the impression of movement in that direction

syphilitic aortitis, are usually heard much better down the left border of the sternum than at the aortic area (second right costal cartilage) Again, both aortic systolic and diastolic murmurs are occasionally maximal at the mitral area (apex beat) It follows that analysis of cardiac sounds and murmurs requires more than geographical data Whilst the propagation of a basal murmur may help to distinguish between aortic and pulmonary responsibility, propagation of a central or apical murmur bears more relation to the intensity of the sound than to its site of origin, and is of little value in differential diagnosis The quality and timing of murmurs, however, are very important, and will be discussed later

The Heart Sounds The first heart sound is due almost entirely to mitral and tricuspid valve closure. Its intensity depends chiefly upon the position of the cusps at the beginning of ventricular systole, partly upon the volume

of lung covering the heart or upon the thickness of the chest wall, and perhaps least upon the degree of ventricular filling and the strength of ventricular contraction – unless changes in these functions are extreme.

The position of the valve leaflets at the beginning of ventricular systole depends upon the P-R interval: the loudest first sound is produced when auricular contraction forces the leaflets wide open immediately before the ventricles contract (P-R around 0.10 second); but when there is a relatively

culatory states is similarly produced in that a relatively high and effective filling pressure keeps the cusps wide open until the last possible moment, whatever the auricles are doing.

The second heart sound is due to aortic and pulmonary valve closure. Although the aortic element may be heard best in the aortic area, in the neck, and at the apex beat, and the pulmonary element in the pulmonary area, no such distinction is entirely reliable. In normal individuals both elements can usually be heard, especially in the second and third left interchondral spaces close to the sternal border In children and adolescents the split is often obvious (grade II), particularly towards the end of inspiration The first element is aortic, the second pulmonary. In adults, recognition of splitting may be more difficult (grade I), but becomes easier with experience Pathological splitting (grade III) is due to delay in pulmonary valve closure, and is usually due to right bundle branch block or possibly to delay in the emptying time of an over-filled right ventricle. Slight delay in aortic valve closure may bring the two elements together and so cause a single second heart sound There seems to be a tendency for this to occur with advancing years With left bundle branch block the aortic element may lag behind the pulmonary element, but rarely so much as to cause more than reversed grade I splitting.

Recognition of a split second heart sound at once proves that both semilunar valves are functioning and thus excludes pulmonary stenosis. Recognition of grade III splitting is also helpful, because the knowledge that right bundle branch block is probably present may be of considerable diagnostic importance

Accentuation of the second heart sound may result from systemic or

artery is unusually close to the anterior surface of the chest, either because it is abnormal or because it is scantily covered by lung and chest wall, the second heart sound is also loud. Conversely, a soft or absent second heart sound is usual in emphysema

The third heart sound and other varieties of triple rhythm are discussed elsewhere (page 164).

Examination of the lungs. Whilst routine examination of all systems is necessary in any speciality, examination of the lungs is peculiarly significant in cardiology for several reasons: to detect any abnormality associated with the pulmonary circulation, e.g. congestion, œdema, infarction, hydrothorax, and the like; to see if there is any pulmonary cause for anoxæmia, especially emphysema; to note whether there are any changes in the lungs which might be secondary to bronchial obstruction due to pressure from some cardiovascular lesion such as pericardial effusion or aneurysm of the aorta; to reveal any thoracic or intra-thoracic cause for cardiac displacement, e.g. scoliosis, pulmonary collapse or fibrosis, pleural effusion, pneumothorax, or elevation of the diaphragm.

Examination of the other systems. There is no need to go into these in detail, but it must be recognised that important clues to cardiovascular diagnosis lie outside that system. Thus atrial septal defect may be suggested by arachnodactyly; rheumatic activity by erythema marginatum, diphtheritic carditis by paresis of accommodation or palatal palsy, beri-beri heart and periarteritis nodosa by polyneuritis, bacterial endocarditis by the combination of fever, anæmia, petechiæ, splenomegaly and clubbing of the fingers; thyrotoxic heart disease by remote findings in the eyes, neck and hands; syphilitic aortitis by signs of syphilis elsewhere, especially in the central nervous system; and so forth.

SPECIAL TESTS

History-taking and routine physical examination are supported by fluoroscopy and electrocardiography. These two methods of investigation are so important that a special chapter is devoted to each (Chapters II and III). There are, however, certain other tests which may be used with advantage in appropriate circumstances, and which may be described conveniently here; some are beyond the scope of the general practitioner, but are included to foster interest and understanding.

Direct measurement of the venous blood pressure. Whilst elevation of the venous pressure is usually detected clinically with little difficulty, there are occasions when it is valuable to check it by direct measurement. The subject should be propped up at an angle of 45 degrees; because patients with orthopnœa cannot lie flat, and the technique should be the same for all cases. The right arm, bared to the shoulder, is abducted to a right angle and supported on pillows so that the antecubital fossa is roughly at heart level. An infusion needle, connected to a spinal manometer or similar graduated glass tube, is then inserted into the antecubital vein, the zero mark on the manometer being placed at the level of the fourth costal cartilage by means of a spirit-level, the height to which blood rises above this mark represents the venous pressure. Alternatively, the zero mark may be placed at the level of the sternal angle or of some other reference point. To avoid clotting, a saline reservoir containing a drop of heparin should be

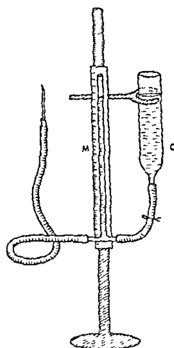


Fig 1 03—Apparatus for measuring the venous pressure
M Manometer graduated in cm
C Citrate or saline reservoir

attached to the system by means of a T-shaped glass connexion, as shown in figure 1.03, a few ml. of the solution being allowed to flow through from time to time. With this modification the manometer contains saline instead of blood. The result should be expressed in cm of water (a horizontal line through the fourth costal cartilage with the patient at 45 degrees cuts the superior vena cava just above its junction with the right auricle), or in cm. of water above or below the sternal angle. If the technique is satisfactory, the saline column should rise and fall gently with respiration, and should rise sharply when *the arm is constricted above the needle. The* normal venous pressure, as so measured, ranges between 2 and 10 cm. of water and averages 5.76 cm. (Wood, 1936); expressed with reference to the sternal angle, it may be plus or minus 0 to 3 cm in relatively horizontal positions

The circulation-time. The circulation-time may be measured from the antecubital fossa to the head and neck, via the heart and lungs Numerous substances may be used for the purpose, and fall chiefly into three groups, illustrated by sodium cyanide, histamine, and sodium dehydrocholate. If 0 25 to 0 5 ml. of 2 per cent sodium cyanide is injected into the antecubital vein, the patient takes a sudden deep breath when the substance reaches the carotid sinus, the respiratory reflex being initiated by direct chemical action (Robb and Weiss, 1934) The end-point is therefore objective Sodium cyanide is rapidly rendered inert by oxidation, so that the test may be repeated almost immediately, if necessary Unfortunately, patients vary considerably in their susceptibility to the drug, and as this cannot be predicted the minimum dose must be tried first the sensation of choking and strangling which may follow too large a dose in sensitive individuals may be very unpleasant.

Histamine phosphate (Weiss, Robb, and Blumgart, 1928), in doses of 0.001 mg. per kg. of body weight in 1 : 5,000 solution, induces a sudden facial flush when it reaches the capillaries of the head and neck. It is not recommended owing to the uncertain end-point and subsequent headache; recorded times are too long.

A 20 per cent solution of sodium dehydrocholate (decholin, suprachol) has been used extensively and has given satisfactory results, but it sometimes causes vomiting (Winternitz *et al.*, 1931). A dose of 3 to 5 ml. is injected

rapidly through a wide-bore needle, the patient having been warned to raise the other hand smartly the instant he should notice a strange taste in or under the tongue. This taste is peculiarly intense and bitter, so that it is difficult for the patient to be mistaken about the moment of its arrival, and objective confirmation may be obtained by the involuntary grimace which accompanies it. The time should be measured from the beginning of the injection to the end-point described, and in normal individuals averages 13.5 seconds, with extremes of 9 to 18 seconds (Wood, 1936). A concentrated solution of saccharin (2.5 G in 4 ml. of water), 5 ml of 10 per cent calcium gluconate, and numerous other substances, may be used instead of decholin, but none have a more definite end-point. Saccharin is less unpleasant, however, does not cause vomiting, and may be injected repeatedly when serial observations are required.

The arm-to-lung-time may be measured by injecting 0 25 ml of ether into the antecubital vein, its arrival in the capillaries of the lung being signalled by a sudden cough or deep breath, and by the smell of ether in the expired air. Amyl acetate may also be used, the smell of pear-drops being unmistakable when it reaches the lungs The normal time averages 6 seconds, and ranges between 3 5 and 8 seconds (Hitzig, 1935). The test has a limited value, as explained on page 163.

The passage of radioactive sodium through the chambers of the heart may be recorded in the form of a time-concentration curve by means of a Geiger-Muller counter, specially fitted with a direct writing attachment (Prinzmetal *et al.*, 1948)

CARDIAC CATHETERISATION

Although first performed by Forssmann (1929) on himself, the introduction of cardiac catheterisation as an aid to clinical diagnosis is largely due to the work of Cournand in the U S A., and of McMichael and Sharpey-Schafer in England. The median cubital vein of either arm is exposed and the tip of a special nylon catheter inserted in the manner of introducing a cannula The catheter, which has been previously washed through with saline, and in the hilt of which is an adaptor connected with a 5- or 10-ml. syringe loaded with saline, is then pushed up the vein under fluoroscopic control, its curved tip being directed medially Any obstruction may be overcome by rotating the catheter a little one way or the other. Kinks at the thoracic inlet may be passed during deep inspiration, sometimes it may be necessary to exchange the catheter for one with a more curved tip, or even to use the other arm Venospasm is avoided by proper skin anæsthesia, and by choosing a catheter that is not too large for the vein When the tip of the catheter lies in the right auricle, the syringe is removed, and the adaptor is connected by means of a rubber tube and Y-piece to a saline manometer and reservoir into which a drop of heparin is added The catheter is flushed from time to time by releasing the clip below the reservoir, or a continuous drip technique may be employed The

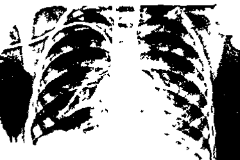




Fig 1 04 (*top*)—Catheter in right branch of the pulmonary artery

Fig 1 05 (*bottom*)—Catheter in right branch of the pulmonary artery (1st oblique position)



Fig. 1 06—Catheter in right branch of the pulmonary artery (2nd oblique position)



Fig. 1 07—Catheter in left branch of the pulmonary artery



Fig 1 08—Catheter in left branch of the pulmonary artery (1st oblique position)

best way to enter the right ventricle is to loop the catheter in the right auricle and to rotate the upwardly directed tip until it faces the tricuspid orifice; if it can then be passed through the valve it is in the right position for entering the pulmonary artery. Success is signalled by a sudden rise of pressure in the manometer and by increased amplitude of pulsation The catheter is then advanced into the pulmonary artery (figs 1.04–1.09). With a saline manometer only mean pressures can be recorded Electrical manometers with optical recording overcome this difficulty, and provide continuous graphic records showing systolic and diastolic levels (Hamilton *et al*, 1934). Ten ml. samples of blood may be taken under paraffin from appropriate chambers for estimation of oxygen unsaturation.



Fig 1 09—Catheter in left branch of the pulmonary artery (2nd oblique position)

Cardiac catheterisation is of value as a means of obtaining samples of mixed venous blood for estimating the cardiac output, in demonstrating certain shunts, and in measuring the pressures in the right side of the heart If 5 litres of blood pass through the lungs per minute, and the arteriovenous oxygen difference is 50 ml. per litre, then the amount of oxygen taken up by the lungs is $5 \times 50 = 250$ ml. per minute In other words, the cardiac output in litres per minute × the arterio-venous oxygen difference in ml per litre = the oxygen consumption in ml per minute. This principle was first enunciated by Fick (1870), and is usually expressed as follows.

$$\text{Cardiac output (litres per min)} = \frac{\text{Oxygen consumption (ml per min.)}}{\text{Arterio-venous oxygen difference (ml. per litre)}}$$

The oxygen consumption may be measured by means of a spirometer in the usual way The arterio-venous oxygen difference is estimated by measuring the oxygen unsaturation of 5 or 10 ml. samples of blood from the right auricle and from the femoral artery, obtained by means of cardiac catheterisation and direct arterial puncture respectively, subtracting one

from the other, and expressing the result in ml. per litre. Blood-gas analysis requires familiarity with Haldane's or van Slyke's apparatus. The normal resting cardiac output is about 5 litres per minute in the horizontal position and 4 litres per minute in the erect position (McMichael and Sharpey-Schafer, 1944). During exercise it may rise to 20 to 30 litres per minute.

Intra-cardiac shunting may be proved by finding significant differences in the degree of oxygen unsaturation in samples of blood taken from the venæ cavæ and right auricle as in atrial septal defect, or from the right ventricle and pulmonary artery as in patent ductus In a normal subject with 100 per cent hæmoglobin, the arterial blood contains about 190 ml oxygen per litre; as the maximum oxygen capacity is about 200 ml per litre (page 17), this gives 10 ml. oxygen unsaturation per litre, which is the figure obtained by gas analysis Mixed venous blood usually gives an unsaturation value of about 60 ml. per litre; this may be expressed as 200 minus 60=140 ml per litre oxygen content; or as $\frac{140}{200} \times 100 = 70$ per cent oxygen saturation Complete mixing is always found in the pulmonary artery, and usually in the right ventricle, but streamlining in the right auricle may give rise to false readings if there is an appreciable difference between superior and inferior vena cava samples Proof of an intra-cardiac shunt is rarely accepted unless the oxygen unsaturation of samples from different parts of the right side of the heart differ consistently by more than 10 ml /litre

The normal mean right auricular pressure lies between −2 and 2 mm. of mercury with reference to the centre of the auricle in the recumbent position, or between −8 and −4 cm of saline with reference to the sternal angle The effective filling pressure of the heart is the auricular pressure minus the negative intra-thoracic pressure, i.e. 0−(−5) mm. Hg = +5 mm. of mercury The mean right ventricular pressure is 10 to 15 cm. of saline above the right auricular pressure; the right ventricular systolic pressure is 20 to 30 mm of mercury (Bloomfield *et al.*, 1946) The mean pressure in the pulmonary artery is about the same as that in the right ventricle, the pulmonary diastolic pressure being very low. Measurement of such pressures may provide valuable information in diagnosis and research

The chief risks of cardiac catheterisation are paradoxical embolism in cases of veno-arterial shunt, rigors due to pyrogens in the apparatus, and subsequent thrombo-phlebitis. Paradoxical embolism may cause hemiplegia or cerebral abscess, and great care must be taken when investigating cases of right to left shunt: heparin should be given through the catheter at the start in a dose of 25 to 50 mg , according to the age and weight of the patient (1 mg per kg. body weight); and air must be rigidly excluded from the system, especially when changing syringes during sampling. Rigors can be very dangerous in cases of severe mitral stenosis or left ventricular failure, when the resulting rise of venous pressure may precipitate an attack

of acute pulmonary œdema. As the rubber connecting tubes carry saline only, the pyrogens may be assumed to come from the lining of the catheter, which should either be destroyed after a rigor or thoroughly cleaned with hydrogen peroxide. Thrombo-phlebitis is rarely serious, but may give rise to transient swelling of the arm and occasionally to pulmonary infarction Infection may be avoided by careful aseptic technique and by giving a massive dose of penicillin immediately after the procedure. In cases with right to left shunt, thrombo-phlebitis should be treated with heparin without delay (see page 454).

Arterial oxygen saturation. With a normal hæmoglobin of 15 gm. per cent, one litre of blood should contain $15 \times 1.34 \times 10 = 201$ ml of oxygen when fully saturated, because 1 G of hæmoglobin is capable of holding 1.34 ml. of oxygen. As normal arterial blood is 95 per cent saturated, it contains, at N.T.P., roughly 190 ml of oxygen per litre, neglecting a small amount held in solution in the serum The demonstration of an abnormal degree of arterial oxygen unsaturation is helpful in proving the existence of a veno-arterial shunt or of some disease of the lungs causing failure of proper oxygenation of the blood in the pulmonary circulation, e g severe emphysema

Samples of arterial blood may be obtained from the femoral artery by direct puncture An ordinary intramuscular needle attached to an all-glass syringe containing a little paraffin should be plunged almost vertically into the vessel The femoral blood pressure then lifts the barrel of the syringe which fills with blood accordingly; no aspiration is necessary On withdrawing the needle the site of puncture should be compressed digitally for at least a minute Some risk is attached to the procedure if the vessel is unduly sclerotic, when a severe hæmatoma may result. The sample of arterial blood is analysed as mentioned in the preceding section

Vital capacity. This is easily measured by means of a spirometer. During normal respiration the amplitude of the graph represents the tidal air, usually about 500 ml The complemental air is registered by the additional upright deflection inscribed when the subject takes a maximum inspiration The reserve air is represented by the additional downward deflection inscribed when the subject takes a maximum expiration Each averages about 1,500 ml The vital capacity is the sum of these three measurements (fig 1 10) and averages 3½ to 4 litres, being higher in men than in women It has been found to be proportional to the surface area of the body, which may be calculated from height and weight by reference to standard tables The vital capacity is decreased particularly in emphysema and in heart failure with pulmonary congestion

Lung volume and residual air. The residual air is that which remains in the lungs after a complete expiration and may be estimated in the following way. The patient is connected with a spirometer containing known quantities of air and oxygen and encouraged to breathe quietly and to become accustomed to the instrument The vital capacity and reserve air are

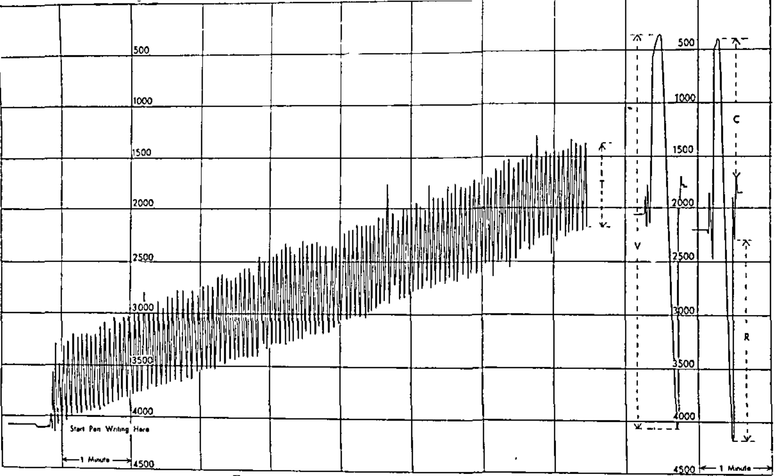


Fig. 1 10—Spirometric tracing from a normal male adult.

T. Tidal air (850 c c)   C Complemental air (1,300 c c)   R Reserve air (1 650 c c)   V. Vital capacity (3,800 c c)

The oxygen uptake = 255 c c per minute

measured in the usual way. Oxygen is admitted at a rate equivalent to its uptake, so that the graph remains flat. The patient is then disconnected, and a known quantity of helium (hydrogen is not altogether safe) is introduced into the system. The percentage of this gas in the spirometer is next measured by means of a Katharometer (McMichael, 1939), and should tally with the calculated percentage. When the patient is again connected to the circuit, helium diffuses into the lungs until equilibrium is reached The capacity of the space into which the gas has diffused may be calculated from the fall in the percentage of helium in the spirometer With certain corrections this represents the reserve air plus the residual air As the former is already known the latter may be calculated by subtraction The total lung volume is the vital capacity plus the residual air.

In emphysema, reduction of vital capacity is balanced by an increase in the residual air, so that the total lung volume remains normal In pulmonary congestion, however, the vital capacity is reduced at the expense of the total lung volume, the residual air remaining unchanged, and is a measure of the amount of extra blood held in the pulmonary circulation.

The jugular phlebogram. The polygraph is an instrument for making simultaneous graphic records of two or more vascular pulsations. Mackenzie (1902) used the ink polygraph, and concentrated on the jugular

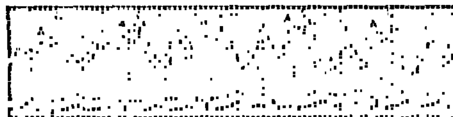


Fig 1 11—Jugular phlebogram

A Auricular contraction
C Ventricular contraction and closure of the tricuspid valve
V The summit signals the opening of the tricuspid valve

phlebogram as a means of analysing abnormalities of rhythm Although the instrument is now rarely used in clinical work, owing to the development of the more fruitful electrocardiograph, it is still necessary to understand the significance of the venous waves in the neck. There are three in each cardiac cycle, labelled a, c, and v (fig 1 11) The first represents auricular contraction and disappears when the auricles fibrillate It may be distinguished clearly in many cases of heart block as an isolated event between two main jugular beats The c wave signals isometric ventricular contraction and closure of the tricuspid valve In the neck it merges into the artefact caused by carotid pulsation The v wave occurs after a longer interval. its rising limb signifies increasing venous pressure resulting from continued venous return against a closed tricuspid valve, and reaches its peak the instant before the valve opens, when the pressure promptly falls. The

summit of the v wave is therefore used as a means of timing the opening of the tricuspid valve, and therefore of the mitral. The reduction of venous pressure causing the trough (x) after the a wave is due to auricular relaxation. The trough (x_1) between c and v represents the negative pressure created by descent of the atrio-ventricular septum and marks the systolic ejection phase. The final trough (y) following the summit v is due to release of auricular pressure following the opening of the tricuspid valve.

Simultaneous jugular phlebograms, electrocardiograms, and phonocardiograms have helped considerably in the elucidation of gallop rhythm, of the third heart sound, and of the opening snap of mitral stenosis. Optical recording has replaced the graphic method employed by Mackenzie, so that errors due to the inertia of levers is minimised.

The arteriogram. There are numerous methods of recording pulsation from any superficial artery, but those in which the graph is optically registered are preferable. They are of limited clinical value, because they reveal little which cannot be discerned with the trained finger. A normal arteriogram (fig. 1.12) usually exhibits two waves, P and D. The former is the percussion wave and represents the rapidly transmitted shock of left

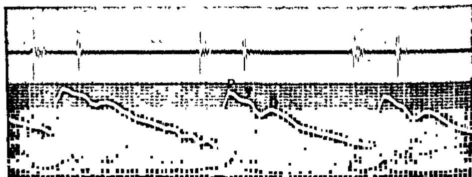


Fig. 1.12—Brachial arteriogram
P Percussion wave T Tidal wave
D Dicrotic wave
(*By courtesy of Drs Frances Gardner and Max Zoob.*)

ventricular contraction; it is a pressure wave and must not be confused with blood flow. Its *velocity is 5 to 8 metres per second and is inversely* proportional to the elasticity of the artery. The length of the wave is 3.5 to 5 metres. D is the dicrotic wave, and is produced by the shock of aortic valve closure. The latter synchronises with the incisura N (dicrotic or aortic notch) which precedes the dicrotic wave. Under certain circumstances, e.g. in combined aortic stenosis and incompetence, a second systolic wave T follows the percussion wave. This is believed to be a tidal wave, the tail of the percussion wave being suddenly augmented by the reflection of its head from the periphery (Bramwell, 1937).

Phonocardiography. The heart sounds were first directly recorded by Frank (1904) and modifications of his original methods are still widely

used. A stethoscope is applied to the chest wall and connected, through a rubber tube, *with a Frank's capsule. This consists essentially of a very thin* rubber membrane to which a small mirror is attached A beam of light is focused on the mirror and reflected onto a camera unit. Electrical amplification was developed by Einthoven (1907) and has been employed in many ways since, but has little advantage over the direct method (Orias and Braun-Menendez, 1939). Tracings should be timed against the jugular phlebogram which is the simplest means of recording all mechanical events in the cardiac cycle (fig 1.13)

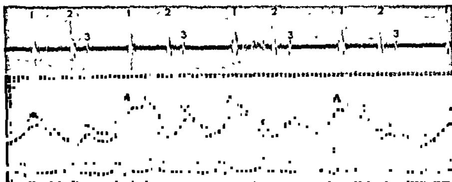


Fig 1 13—Phonocardiogram synchronised with electrocardiogram and jugular phlebogram Note the third heart sound and absence of murmur
(*By courtesy of Drs Frances Gardner and Max Zoob*)

Phonocardiography has been largely restricted to academic and research units, but deserves to be employed more widely as a routine aid to diagnosis. It has proved valuable in the elucidation of extra heart sounds and in the precise timing of murmurs

Ballistocardiography The ejection of blood from the heart is accompanied by a recoil of the whole body in the opposite direction proportional to the mass ejected. If the body is placed horizontally on a specially constructed couch the recoil movements may be graphically recorded. The ballistocardiogram has been used chiefly to measure changes in cardiac output, but the form of the graph may give other information about the function of the heart (Starr, 1941; Starr and Mayock, 1948).

GENERAL TESTS

Of more general tests, examination of the urine, renal function tests, the blood count, the blood Wassermann reaction and the Kahn reaction, and the basal metabolic rate are most valuable in cardiovascular work. Their technique will not be described; but it is pertinent to make a few remarks concerning them

Examination of the urine The urinary findings may be helpful in cardiology in four main ways First, albuminuria is commonly present in con-

gestive heart failure, the diagnosis of which should be carefully checked in its absence Second, diabetes mellitus may be associated with coronary or peripheral atherosclerosis. Third, red cells are nearly always found in the [illegible]

urinary findings in hypertension are of paramount importance.

Renal function tests The blood urea, urea clearance, and urine concentration tests are those commonly employed Their chief value is in hypertensive heart disease *It should be borne in mind that the blood urea is* often raised, up to about double the normal, in congestive heart failure from any cause, with a corresponding fall in urea clearance Renal function tests are usually normal in embolic nephritis and in renal infarcts.

Blood count. Increased activity of the red marrow, with reticulocytosis, is frequent in congestive heart failure, especially when associated anoxæmia can be demonstrated, as in pulmonary heart disease. Polycythæmia is far less common, except in congenital heart disease with cyanosis. The effect of anæmia on the heart is described in Chapter XIX Here, it is only necessary to say that the anæmia which may be associated with rheumatic or bacterial endocarditis, and with malignant or chronic nephritic hypertension, is usually normocytic and orthochromic. Anæmia associated with myxœdema is variable, and may be orthochromic or hypochromic, in the latter, however, iron deficiency is usually present as well.

Leucocytosis *may occur in rheumatic carditis, and in bacterial endo*carditis, but normal white counts are common in both, and indeed leucopenia occurs in about one-third of cases of bacterial endocarditis The leucocytosis of myocardial infarction is transient, lasting little longer than the fever Repeated white counts are necessary as a check against the development of agranulocytosis during the course of thiouracil therapy, and during prolonged prophylactic treatment with sulphonamides.

The erythrocyte sedimentation rate. The E.S R. is helpful in cardiology in several ways it is the most sensitive guide to the presence of activity in rheumatic carditis, it is accelerated in syphilitic aortic incompetence, which may thus be distinguished from old rheumatic and atherosclerotic varieties; its characteristic behaviour in myocardial infarction serves as a useful index of progress; its acceleration in the various forms of hypertension runs more or less parallel to the degree of renal involvement, being rapid in nephritic and malignant hypertension, and normal in the benign type; it is retarded by congestive heart failure, the development of which may suddenly alter a reading of 80 or so, in rheumatic carditis for example, to one below 10. Readings are normal in congenital heart disease (or low if there is polycythæmia), in old rheumatic heart disease, in uncomplicated angina pectoris, in thyrotoxicosis, and in myxœdema (Wood, 1936)

The basal metabolic rate. As thyrotoxicosis and myxœdema are not uncommon causes of cardiovascular disorder, and thiouracil is sometimes

used to induce myxœdema in stubborn cases of angina pectoris and congestive heart failure, the B.M.R. is frequently measured in cardiovascular clinics. It is important, therefore, to understand that readings are often elevated in heart failure from any cause, if there is dyspnœa, for under such circumstances truly basal conditions cannot be realised.

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RADIOGRAPHIC DIAGNOSIS

TECHNIQUE

THERE are, at present, five radiological methods applicable to cardiology: fluoroscopy, orthodiagraphy, teleradiography, kymography, and angiocardiography. Fluoroscopy (screening) is a routine diagnostic procedure; orthodiagraphy is the construction of a simple tracing of the size and shape of the heart in any specified position, as a supplement to fluoroscopy, teleradiography gives a more accurate record, and should be preferred when facilities permit, kymography is a method of recording the character and amplitude of cardiac pulsation; angiocardiography is the study of individual cardiac chambers or vessels with the aid of intravascular contrast media.

FLUOROSCOPY

With modern X-ray equipment a remarkably clear view of the heart may be obtained. The patient should be stripped to the waist and pressed close to the viewing screen The diaphragm, which controls the diameter of the beam emitted from the X-ray tube, is first opened wide, in order to view the thoracic contents as a whole In this preliminary survey attention is paid to the lungs, to the costophrenic angles, and to the general size and shape of the heart The diaphragm is then constricted so that only the heart can be seen, and the latter is observed more critically The size, shape, and pulsation of each part should be noted in regular sequence On the right side (fig. 2 01), a faint, slightly concave line, representing the superior vena cava, descends from the sterno-clavicular region, close to the shadow of the vertebral column, until it meets the ascending aorta, which both displaces it to the right and causes it to become convex Below is the border of the right auricle, which usually meets the diaphragm at a slightly acute

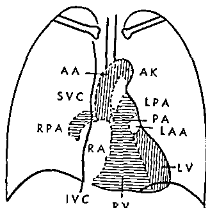


Fig 2 01—Diagram of antero-posterior view of the heart as seen fluoroscopically
S V C Superior vena cava
A A Ascending aorta,
P A Pulmonary artery,
R V Right ventricle,
R A Right auricle,
A K Aortic knuckle,
L V Left ventricle,
L A A Left auricular appendage
I V C Inferior vena cava

angle. The left border of the normal heart is made up of three convex curves from above downwards, these are the aortic knob or knuckle, the pulmonary arc, and the contour of the left ventricle. Between the last two there is a small neutral segment or point of opposing movement which marks the left auricular appendage; above it the pulmonary artery expands during systole, while below the left ventricle contracts. The hilar shadows are chiefly vascular. the right pulmonary artery may be seen dividing early into upper and lower branches, the former being indistinct, the latter sweeping downwards in a well-defined arc; the left limb of the pulmonary artery forms the main pulmonary arc described above.

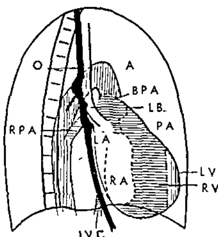


Fig 2 02—Diagram of right anterior oblique view of the heart as seen fluoroscopically (1st oblique position)

O	Barium-filled oesophagus,
B P A	Bifurcation of the pulmonary artery,
L A	Left auricle
A	Aortic arch
L B	Left bronchus,
I V C	Inferior vena cava
V	Ventricles (L and R)
P A	Pulmonary arc,
R A	Right auricle

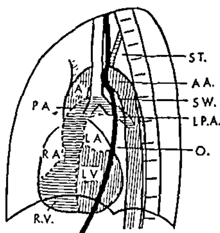


Fig 2 03—Diagram of left anterior oblique view of the heart as seen fluoroscopically (2nd *oblique position*)

R V	Right ventricle,
L V	Left ventricle,
A A	Aortic arch,
S W	Sub-aortic window,
O	Barium-filled oesophagus,
R A	Right auricle,
L A	Left auricle,
P A	Pulmonary arch,
S T	Supra-aortic triangle

The patient is then turned into the first, or right anterior, oblique position The observer should place his gloved hands on the patient's hips, and manually rotate him (so that the right shoulder is brought to the front) until the position is satisfactory The arms should be extended, the left forwards and outwards, the right backwards and outwards In this view *(fig. 2 02) the ventricular shadows are superimposed and the right auricle* is rotated towards the front, so that little can be learned about these three chambers; on the other hand, the left auricle is outlined clearly, as it forms the upper part of the posterior border of the heart. Just anterior to the top of the left auricular curve, a rather dense round shadow may be seen, due to the bifurcation of the pulmonary artery; it is connected with the anterior

ventricular border by a convex line representing the root of the pulmonary artery and conus of the right ventricle. Above it are the superimposed shadows of the ascending and descending parts of the aortic arch If the patient is made to swallow a barium emulsion of the consistency of thick cream, the œsophagus is outlined at the back of the heart; under favourable conditions it is indented in turn by the arch of the aorta, by the pulmonary artery and left bronchus, and by the left auricle. The left bronchus may be seen between the œsophagus and the rounded shadow of the dividing pulmonary artery. Between the œsophagus and the vertebral column there should be a translucent space.

In the second, or left anterior, oblique position (fig. 2 03), the patient is turned to the right through an angle of about 45 degrees, the left shoulder being brought forwards In this view the two ventricles appear side by side, the left forming the posterior border of the heart shadow and the right the anterior, so that their contours can be readily compared. The shadow of the right auricle overlaps that of the right ventricle; the shadow of the left auricle lies posteriorly above the left ventricle Cranially, the aorta and pulmonary artery may be seen as two arches, one above the other, separated by a light-space known as the sub-aortic window, and crossed by the translucent trachea and left bronchus. The aortic arch and descending aorta are well defined and shaped like an inverted J, but the pulmonary artery is less distinct Above the aorta is another light-space, the supra-aortic triangle, bounded by the vertebral column posteriorly, by the left subclavian artery anteriorly, and by the aortic arch below. The barium-filled œsophagus is deflected to the patient's right as it crosses the aortic arch, then lies in close relation to a short segment of the descending aorta, leaves that vessel at about the level of the pulmonary artery, and courses downwards and to the subject's right across the shadow of the left ventricle

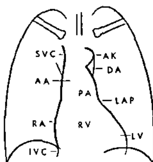


Fig 2 04—Orthodiagram of a normal subject (A P view)

S V C	Superior vena cava,
I V C	Inferior vena cava
P A	Pulmonary arc,
L A P	Left auricular appendage,
A K	Aortic knuckle,
R V	Right ventricle,
R A	Right auricle,
L V	Left ventricle,
A A	Ascending aorta
D A	Descending aorta

ORTHODIAGRAPHY

Clips should be fitted to the viewing screen to enable tracing paper to be held firmly in position To make an accurate tracing of the heart shadow, or orthodiagram (fig 2 04), special attention should be paid to five points First, the position of the patient must be properly adjusted to the view required, he must be pressed firmly against the screen, and he should hold on to some support so that he can remain still Second, the tracing should be made in mid-inspiration, and as it cannot be completed in one period of breath-holding, lines which move with respiration should be checked

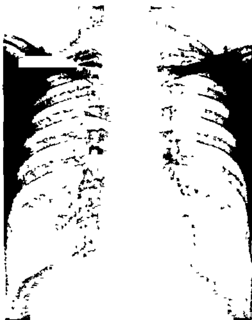


Fig 2 05—Teleradiogram of a normal subject (A P view)



Fig 2 06—Teleradiogram of a normal subject (1st oblique position)



Fig 2 07—Teleradiogram of a normal subject (2nd oblique position)

more than once. Third, to avoid distortion the cardiac outline must be traced by means of parallel rays: this is accomplished by constricting the diaphragm to the smallest aperture consistent with adequate visualisation. Fourth, the greatest accuracy must be maintained when tracing the interior thoracic wall at its widest point, and the lateral borders of the cardiac shadow, so that the cardio-thoracic ratio is reliable. Fifth, the finished orthodiagram should be checked against the shadows traced to make sure the patient has not moved during the procedure.

Fluoroscopes suitable for cardioscopy are so constructed that the X-ray tube may be moved easily in any direction by the lever which operates the diaphragm. In making the tracing, the small light-spot is run swiftly over the contours of the heart, great vessels, clavicles, interior thoracic wall, and diaphragm. With experience it may be completed very quickly, without danger of over-exposing the patient or over-heating the tube, nevertheless, a good technician switches off the current whenever momentarily disengaged. Fluoroscopy and orthodiagraphy are usually carried out with a power of 60 kilovolts and a current of 3 to 4 milliamps; but with obese subjects it may be necessary to step-up the kilovolts to 65 or 70, in order to obtain sufficient penetration Tracings are made with a wax pencil, and it is helpful to add signs denoting the degree and direction of pulsation of important chambers and vessels.

TELERADIOGRAPHY

Skiagrams of the heart are always taken at a tube-screen distance of at least 6 feet, preferably of 7 feet, to avoid distortion by diverging rays. The duration of exposure should be half a second, to ensure a diastolic record To obtain a systolic record, a very short exposure and a special timing device are required. Skiagrams of the oblique views are best taken when the most informative degree of rotation has been ascertained by previous fluoroscopy The normal appearances are illustrated in figures 2 05–2 07.

KYMOGRAPHY

A specially constructed kymograph may be attached to a teleradiograph for the purpose of recording cardiac pulsation (Stumpf, 1931) A lead screen, containing horizontal slits 11 mm apart, is interposed between the film and the patient's chest, and made to descend 1 cm during one complete cardiac cycle The timing of the exposure is adjusted to synchronise with the descent of the grid. In kymograms so obtained, the lateral borders of the heart and great vessels appear toothed, like the edge of a saw (fig 2 08), the ventricular crests representing diastole, the troughs systole Pulsation is recorded in only one dimension, i e in a plane parallel to the film; but if the three standard views are photographed, the records are sufficiently comprehensive

The electrokymograph is a device for securing an accurate graphic record of pulsation at any point on the cardiac border (Henny and Boone,



Fig 2 08—Normal kymogram (A P. view)
(By courtesy of Dr Jenner Hoskin)

1947). A photosensitive pick-up unit is placed between the patient and the screen so that the lead slit aperture lies across the border of the heart at the point where it is desired to record pulsation The amount of light transmitted through the aperture varies with the movements of the cardiac border, and is recorded graphically by means of a galvanometer operated by the photo-electric cell. The interpretation of the graph is assisted by a simultaneous jugular phlebogram or other reference tracing.

ANGIOCARDIOGRAPHY

Individual cardiac chambers may be visualised by introducing 20 to 60 ml. of 70 per cent aqueous solution of diodrast or other contrast media (e g. diodone) intravenously (Robb and Steinberg, 1938), its course being recorded by means of serial skiagrams taken at intervals of one-half to one second with the aid of a rapid casette changer (Sussman, Steinberg and Grishman, 1941); or serial fluorophotographs may be obtained by means of a special camera or cinematograph (Stewart, Breimer and Maier, 1941). Contrast outlines of the right and left sides of the heart may thus be studied separately.

Patients may be seated or lying down. A long cannula of 6 to 9 inch length of wide bore plastic tubing is inserted into the antecubital vein and tied in position A 50-ml. syringe is used and the diodone is injected through the cannula as rapidly as possible—usually within two or three seconds, according to the volume. If a special camera, multiple casette changer, or cinematograph is not available, good pictures of the right side of the heart (fig. 2.09) may be obtained by exposing a film the instant the plunger is home. To obtain a satisfactory skiagram of diodone in the left side of the heart (fig 2.10) without a special photographic unit is more difficult; but the technique is facilitated by measuring the circulation time beforehand If 5 ml of saccharine or decholine is used for this purpose, the time obtained will prove too long to record the left-sided angiocardiogram; for the large volume of diodone injected increases the speed of the circulation considerably. It has been found by experience that this momentary acceleration almost halves the circulation time Due allowance should be made for this when calculating the best time to expose the film Alternatively, however, the same cannula and the same volume of fluid used for angiocardiography may be employed for measuring the circulation time, diluted saccharine giving a satisfactory end-point. Under these circumstances the times should be identical

The method has already been of service in determining the nature of the bump between the pulmonary artery and left ventricle in cases of mitral stenosis, showing it to represent the left auricle rather than the conus of the right ventricle (Robb and Steinberg, 1939, Grishman, Sussman and Steinberg, 1944), in establishing the diagnosis of certain congenital shunts, e g. Fallot's tetralogy (Stewart, Breimer and Maier, 1941), patent ductus (Steinberg, Grishman and Sussman, 1943), severe pulmonary stenosis

(a) Antero-posterior view

(b) Second oblique position

(a) Antero-posterior view



(b) Second oblique position

Fig 2 10—Normal angiocardiogram of the left side of the heart

with atrial septal defect, Eisenmenger's complex, and tricuspid atresia; in demonstrating coarctation of the aorta (Grishman, Steinberg and Sussman, 1941) and partial or complete superior vena cava obstruction (Taylor and Shulman, 1942); and in distinguishing aneurysms of the aorta or pulmonary artery from other mediastinal masses (Thompson, 1941)

CARDIAC MEASUREMENTS

Numerous measurements have been elaborated to serve as indices of enlargement of the heart, or of one or more of its chambers, but they do not compare with expert opinion based on the methods already outlined. The most reliable is the cardio-thoracic ratio, which is the transverse diameter of the heart (fig. 2.11) over the widest internal diameter of the thorax, and which should not exceed 0.5 In normal adults the transverse diameter of the heart averages 12 2 cm in the male, and 11 cm in the female, the range being 8 to 14 5 cm. (Roesler, 1937)

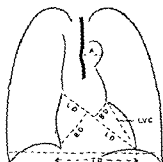


Fig 2 11—Diagram showing the common cardiac measurements

T D Transverse diameter,
B D Broad diameter,
A Width of aorta,
L D Long diameter,
L V C Left ventricular chord

The long diameter is measured from the junction of the superior vena cava and right auricle to the apex of the left ventricle, and lies between 10 and 15.5 cm, averaging 13 cm (Roesler, 1937). It is especially increased in cases of left ventricular enlargement; but it is also relatively increased in the long narrow heart of asthenic subjects

The broad diameter is the sum of two perpendiculars drawn from the long diameter to the right cardio-phrenic angle below, and to the point of opposing movement on the left border of the heart above, and measures 7 to 11 cm. in normal adults, with an average of 9 cm (Roesler, 1937). It may be increased in cases of mitral stenosis and pulmonary heart disease when the transverse and long diameters are normal

The location of the point of opposing movement is important; for it tends to be raised or lowered according to whether enlargement is mainly left or right ventricular respectively Similar significance is attached to the length of the chord which subtends the arc of the left ventricle, measured from the point of opposing movement to the left cardio-phrenic angle. this line is normally 6 to 12.5 cm long, and averages 9 cm (Roesler, 1937).

The antero-posterior diameter of the heart is measured from teleradiograms taken in the lateral position, and varies between 7 and 11 cm, with an average of 9 cm. It is a useful check on the significance of an increased transverse diameter; for if this is due to cardiac enlargement, the antero-

posterior diameter should be increased proportionately; whereas if it is due to depression of the sternum, the depth of the heart is decreased The antero-posterior diameter is especially increased in mitral stenosis

The width of the aorta (2 to 3 cm.) may be measured in the antero-posterior or oblique positions, whichever presents the clearest view of two sides of the vessel. In the antero-posterior view, the measurement should be made from the left side of the barium-filled œsophagus to the left border of the aortic knuckle; but it is only valid when the posterior part of the aortic arch passes directly backwards, i e. in a direction perpendicular to the frontal plane. In the oblique views barium in the œsophagus may also be helpful: in the second oblique position, for example, the œsophagus may be deflected abruptly as it crosses the aorta, so that the width of the vessel is seen clearly. In practice, a normal aorta is most easily measured in the antero-posterior view; a syphilitic, atheromatous, or unfolded aorta in the second oblique view.

NORMAL VARIATIONS

Both the size and shape of the heart vary greatly in normal individuals thus in children and adolescents the pulmonary artery may be relatively prominent (fig. 2.12); in lean asthenic subjects the heart may be elongated and central in position (fig. 2 13), in short stocky individuals it is apt to lie transversely (fig. 2 14).

Displacement or rotation of the heart to left or right is often due to scoliosis, the common finding being displacement of the heart to the left, the spinal curvature being convex to the right. Rotation of the spine without conspicuous lateral curvature may cause considerable displacement or rotation of the heart. When cardiac displacement is due to partial collapse of the lung, increased translucency of the over-expanded normal lung on the same side is usually observed, and is a valuable sign when the collapsed part cannot be seen

Slight enlargement, particularly of the left ventricle and of the transverse diameter, is often seen in patients with slow heart rates, whether due to sinus bradycardia, sino-auricular block, or to heart block. The enlargement depends upon increased diastolic filling, the slow rate being compensated by a large stroke-volume (fig. 2 15) Slight enlargement of similar type may be encountered in athletes, in some it may be explained by sinus bradycardia, which is common in these subjects; but in others it may be due to the extra demands which have been made on the heart

In obese subjects the left cardio-phrenic angle may be filled out by a triangular pad of fat (fig. 2 16), this must not be confused with left ventricular enlargement. In cases of depressed sternum the antero-posterior skiagram may reveal general enlargement of the heart shadow; but in the oblique views the depth of the heart is seen to be correspondingly reduced (fig 2 17)

When such causes can be excluded, and unsuspected enlargement of the

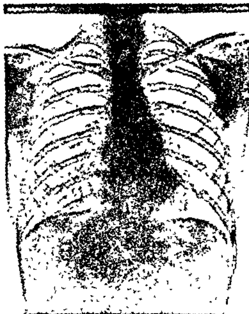


Fig 2 12 Teleradiogram of a child showing relative prominence of the pulmonary artery



Fig 2 13—Transversely placed heart in a short stocky subject

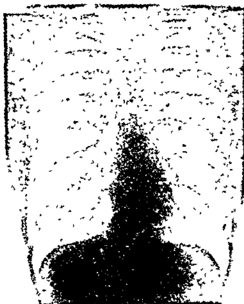


Fig 2 13—The elongated *centrally* placed heart of a lean asthenic subject



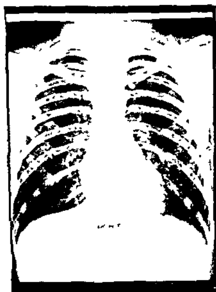
Fig 2 15—Relatively large diastolic heart-size in a subject with sinus bradycardia



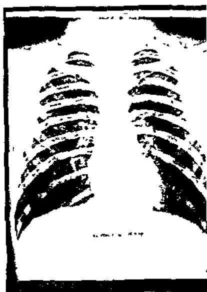
Fig 2 16—Teleradiogram of an obese subject, showing a triangular opacity at the apex of the heart (pericardial fat)



Fig 2.17—Apparent enlargement of the heart in a case of depressed sternum



(a) The heart in diastole



(b) The heart in systole

Fig 2 18—Teleradiograms of the same patient taken with short exposures, showing difference in rise of heart shadow in diastole and systole

cardiac silhouette is revealed by a skiagram, it is wise to check the technique employed Portable X-rays, or pictures taken with the patient lying or sitting, may be misleading owing to distortion. Short exposures may catch the heart in systole and a skiagram so obtained may be appreciably smaller than one photographed in diastole (fig. 2.18).

The heart may be smaller than normal in many wasting diseases, when atrophy takes place, but this is of little practical importance.

RADIOGRAPHIC ABNORMALITIES

The illustrations referable to this section may be found in other chapters, but for the sake of convenience are also reproduced here

ABNORMALITIES OF THE AORTA

Saccular aneurysm (fig. 2 19, a and b) is pathognomonic of syphilis. It may be distinguished from other space-filling lesions by its intimate connexion with the aorta in all views, by calcification of its walls, and by its

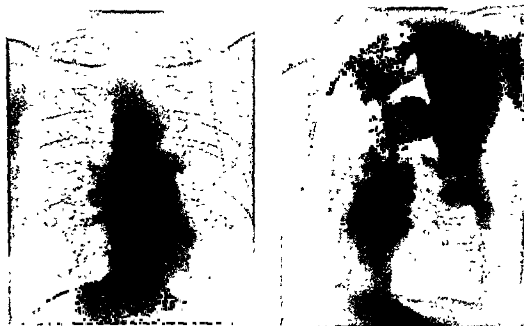


Fig 2 19—Saccular aneurysm of the aorta
(a) Antero-posterior view. (b) Second oblique position
(By courtesy of Sir John Parkinson)

pulsation; a thrombosed sac, however, may not pulsate. Angiocardiography is helpful in doubtful cases. Fusiform aneurysm (fig. 2.20) is usually associated with aortic incompetence and is also practically diagnostic of syphilis; it should be distinguished from undue prominence of the aorta such as that commonly found in other forms of aortic incompetence (fig.

2.21); occasionally it is due to dissection associated with cystic medial necrosis of the aorta. Syphilitic aortitis without aneurysm or fusiform dilation cannot be diagnosed radiologically with assurance, although irregularities of calibre, if clearly demonstrable, are suggestive.

Unfolding of the aorta may occur in aortic valve disease, in hypertensive heart disease, and in atherosclerosis. The ascending limb is conspicuous, the knuckle is unduly prominent, and the descending limb appears to the



Fig 2 20 (*a*)—Fusiform aneurysm of the aorta (antero-posterior view)



Fig 2 20 (*b*)—Fusiform aneurysm of the aorta (2nd oblique position)

patient's left in the antero-posterior view (fig. 2 22). In the second oblique position the arch is wider than normal, and its posterior part may pull the œsophagus backwards (fig 2 23) Vigorous pulsation proclaims aortic incompetence rather than hypertension or atherosclerosis.

Tortuosity of the aorta is characteristic of atherosclerosis; it is best seen in the second oblique view, but may be so marked that the descending limb appears to the right of the heart shadow in the antero-posterior view (fig. 2 24) Calcification of the aorta (fig 2 25) is also characteristic of atherosclerosis, but may occur in the wall of a syphilitic aneurysm

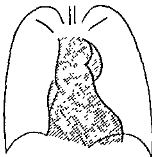


Fig. 2 24 — Orthodiagram illustrating tortuosity of the aorta

Coarctation of the aorta (fig 2 26) may be recognised by a relatively small, absent or elongated aortic knuckle, by notching of the ribs, and by the angiocardiographic demonstration of the constriction itself In addition,



Fig 2 21—Prominence of the aorta due to rheumatic aortic incompetence



Fig 2 22—Unfolding of the aorta in hypertensive heart disease



Fig 2 23—Unfolding of the aortic arch illustrated by barium in the œsophagus.



Fig 2 25—Calcification of the aortic arch

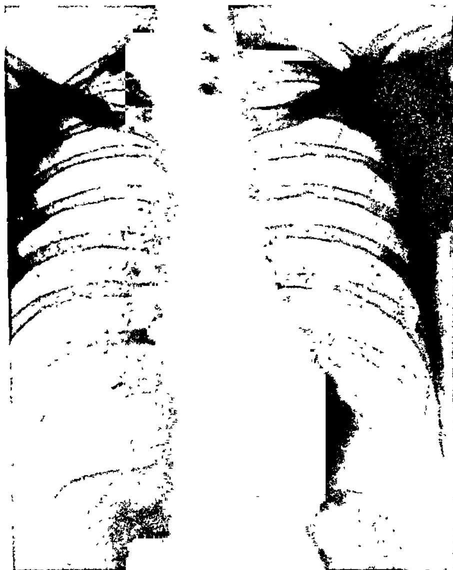


Fig. 2 26—Coarctation of the aorta showing hypoplasia of the aorta, and notching of the inferior margins of the ribs

the left ventricle is usually enlarged. Absence of the aortic knuckle is also associated with congenital right-sided aorta, but the latter may be distinguished by the behaviour of the barium-filled œsophagus which is then deflected to the patient's left, instead of to his right, as it crosses the aorta (fig. 2 27)

Hypoplasia of the aorta is rare as a solitary congenital abnormality, but is common in association with certain other congenital or acquired lesions, especially atrial septal defect and mitral stenosis The aortic knuckle is small and its pulsation diminished (fig. 2.28).



(a) Antero-posterior view



(b) First oblique position

Fig 2 27—Right-sided aortic arch illustrated by means of barium in the œsophagus

(By courtesy of Sir John Parkinson)

ABNORMALITIES OF THE LEFT VENTRICLE

Left ventricular enlargement is encountered chiefly in hypertensive heart disease and aortic valve disease, but it is also seen in patent ductus arteriosus and in organic mitral incompetence, and may occur in various conditions as part of general enlargement. It is easily recognised by the density and bulk of the left ventricular shadow in the antero-posterior and second oblique positions, by increase in the transverse and long diameters of the heart and of the left ventricular chord, and by elevation of the point of opposing movement (figs. 2.29a and 2.29b). In hypertension and aortic valve disease the shadows of the unfolded aorta and of the heart itself may be compared either to two ovals, set at right angles, or to the shape of a boot.

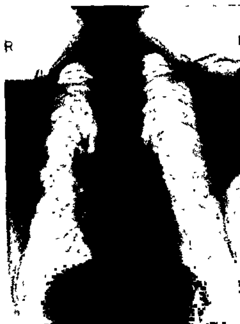


Fig. 2 28—Hypoplasia of the aorta in a case of mitral stenosis



(a) Antero-posterior view



(b) Second oblique position

Fig 2 29—Enlargement of the left ventricle due to syphilitic aortic incompetence

When there is left ventricular failure, the hilar shadows are exaggerated, representing engorged pulmonary vessels (fig. 2.29a), and there may be fan-shaped mottling spreading outward towards the periphery if there is pulmonary œdema (fig. 2.30) Hydrothorax may be present, and if unilateral is usually left-sided (Bedford and Lovibond, 1941).



Fig 2 30—Acute pulmonary œdema due to left ventricular failure in a case of malignant hypertension

Left ventricular aneurysm may present as a bulge on the left border of the heart, usually towards the apex (fig 2.31), and may exhibit paradoxical pulsation. Myocardial infarction may be located with precision in some cases by the fluoroscopic demonstration of an area with absent or paradoxical pulsation. This can be well shown by kymography (fig 2.32)

Fig. 2.31—Left ventricular aneurysm.

Fig. 2.32—Kymogram showing absence of pulsation over an antero-lateral infarct of the left ventricle.
(By courtesy of Dr. Jenner Hoskin)



Fig. 2 33—Dilatation of the left auricle forming a hump between the pulmonary arc and left ventricle in a case of organic mitral incompetence

DILATATION OF THE LEFT AURICLE

Conspicuous dilatation of the left auricle invariably means organic mitral valve disease; but the chamber may be unduly full in cases of left ventricular failure. In the antero-posterior view it may appear as a bump on the left border of the heart between the pulmonary artery and left ventricle (fig 2 33), where it has been mistaken for the conus of the right ventricle The best proof that this bump represents a dilated left auricle is afforded by

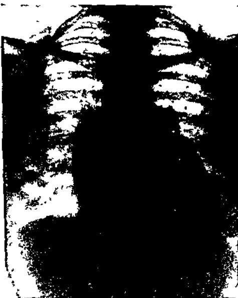


Fig 2 34—Dilatation of the left auricle seen on both borders of the heart in the antero-posterior view in a case of mitral stenosis



Fig 2 37—Dilatation of the left auricle seen in the 2nd oblique position with barium in the œsophagus Case of mitral stenosis

angiocardiography (Grishman, Sussman and Steinberg, 1944), by passing a catheter into the area *via* a patent foramen ovale, or by observing its pulsation in cases of heart block or mitral incompetence. On the right border of the heart an enlarged left auricle may throw a convex shadow above, but overlapping, that of the right auricle (fig 2 34) The barium-filled œsophagus is usually deflected to the patient's right in the antero-posterior view

In the right anterior oblique position the œsophagus is displaced backwards in an abrupt manner immediately below the left bronchus and pulmonary artery (fig 2 35), the antero-posterior diameter of the heart being increased, and the retrocardiac space decreased, correspondingly Backward displacement of the œsophagus from an enlarged left ventricle is rarely so abrupt or so high, but on occasions it may be indistinguishable (fig. 2 36) In the left anterior oblique position an enlarged left auricle

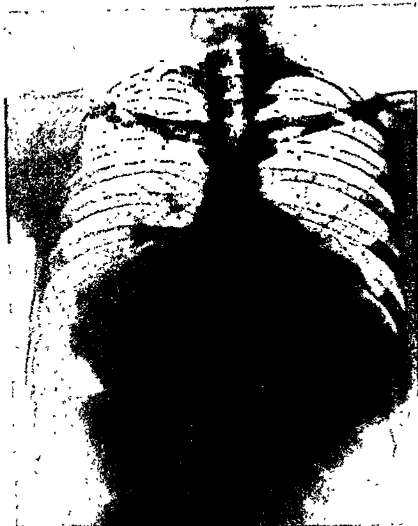


Fig 2 38 (a)—Aneurysmal dilatation of the left auricle in a case of mitral stenosis Antero-posterior view.



Fig. 2 38 (b)—Aneurysmal dilatation of the left auricle in same case of mitral stenosis First oblique position

causes the œsophagus to be deflected backwards above the shadow of the left ventricle (fig. 2 37)

Aneurysmal dilatation of the left auricle (fig. 2.38 a and b) may be caused by rheumatic mitral incompetence or stenosis, but it is probable that a high degree of auricular muscle damage is an important contributory factor.

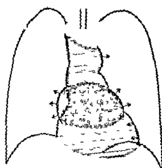


Fig 2 39—Orthodiagram illustrating expansile pulsation of the left auricle during ventricular systole in a case of organic mitral stenosis

Systolic expansile pulsation of the left auricle is pathognomonic of mitral incompetence, usually organic It is especially convincing when seen on both borders of the heart in the antero-posterior view (fig 2 39) In the first oblique position, minor degrees of backward pulsation of the left auricle are often seen and must be regarded as normal, but the quality and amplitude of the movement in organic mitral incompetence are most impressive and are easily recognised with experience Electrokymographic tracings should prove helpful in doubtful cases

ABNORMALITIES OF THE PULMONARY ARTERY

Dilatation of the pulmonary artery occurs chiefly in three congenital and in three acquired lesions, namely, patent ductus arteriosus, atrial septal defect, and pulmonary stenosis with closed septa, on the one hand; and mitral stenosis, pulmonary heart disease and beri-beri, on the other. Rare causes include the Eisenmenger complex and capricious cases of patent interventricular septum without a dextraposed aorta; sometimes, no explanation is found

In patent ductus arteriosus (fig. 2.40) dilatation and exaggerated pulsation of the pulmonary artery and its proximal branches are usually associated with a hyperkinetic aorta, enlargement of the left ventricle and fullness of the left auricle. Angiocardiography may reveal a shadow which resembles a small aneurysm of the inferior margin of the aortic arch where it is joined by the ductus (Steinberg *et al*, 1943) Atrial septal defect (fig. 2 41) is characterised by gross dilatation and conspicuous pulsation of the pulmonary artery and its two main branches; by a heavily marked peripheral pulmonary vascular tree, by considerable enlargement of the right ventricle and right auricle, especially if there is associated mitral stenosis (Lutembacher's syndrome); and by hypoplasia of the aorta (Bedford, Papp and Parkinson, 1941) In pulmonary stenosis with closed septa, dilatation and visible pulsation of the pulmonary artery are more or less confined to the main vessel (fig 2.42), and are slight or moderate in degree; the right ventricle is enlarged, but not the auricle (unless there is failure). In Eisenmenger's complex considerable dilatation of the pulmonary artery

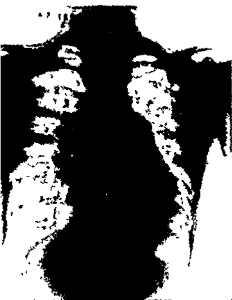


Fig 2 40—Dilatation of the pulmonary artery and its branches, associated with left ventricular enlargement due to patent ductus



Fig 2 42—Dilatation of the pulmonary artery in a case of pure pulmonary stenosis



Fig 2 43—Dilatation of the pulmonary artery in a case of Eisenmenger's complex
(By courtesy of Dr Maurice Campbell)



Fig 2 44—Dilatation of the pulmonary artery associated with pulmonary congestion in a case of mitral stenosis

Fig. 2 41—Dilatation of the pulmonary artery and its branches associated with hypoplasia of the aorta and right ventricular enlargement in a case of atrial septal defect.



(a) Antero-posterior view



(b) First oblique position

Fig 2 45—Dilatation of the pulmonary artery and its main branches in a case of chronic pulmonary heart disease due to emphysema



Fig 2 45 (c)—Second oblique position



Fig 2 46—Dilatation of the pulmonary artery due to primary or idiopathic pulmonary hypertension

is the rule (fig. 2.43); as the shunt is from right to left, the aorta is not hypoplasic and the peripheral pulmonary vascular shadows are inconspicuous The appearances in ventricular septal defect resemble those of patent ductus, but the pulmonary artery is usually less dilated

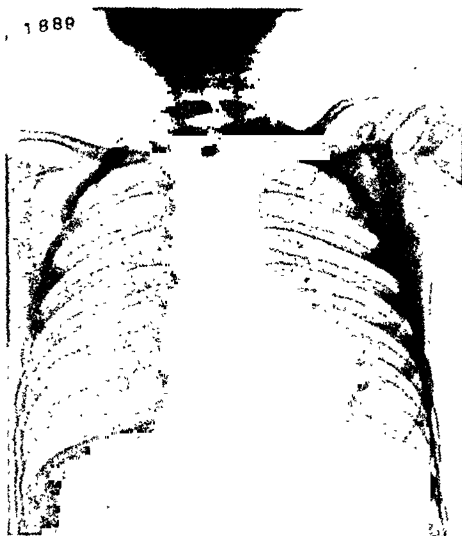


Fig 2 47—The Cœur en sabot due to Fallot's tetralogy.

Of the acquired lesions, mitral stenosis may usually be recognised by the presence of aortic hypoplasia and enlargement of the left auricle, but these are not always evident (fig 2.44); moreover, if there is aortic incompetence as well, the aorta may be prominent and the left ventricle enlarged. If there is a bump between the pulmonary artery and left ventricle in the antero-posterior view, mitral stenosis (or incompetence) is certain, whether the shadow is believed to represent the left auricle or the conus of the right

ventricle; for it does not occur in any other condition. In pulmonary heart disease, the pulmonary artery and its main branches are moderately prominent (fig. 2.45a). Owing to associated emphysema, the rounded shadow of the bifurcation of the pulmonary artery appears especially dense, by contrast, in the first oblique position (fig. 2.45b), and the pulmonary arc is unusually well defined, even to dwarfing the aortic arch, in the second oblique position (fig. 2.45c). The aorta is more prominent in the antero-posterior view than in the other congenital and acquired lesions mentioned above, owing to the high cardiac output. The right ventricle is enlarged, and the right auricle is abnormally full. Pulmonary heart disease without emphysema, so-called primary pulmonary vascular sclerosis (fig. 2.46) or idiopathic pulmonary hypertension, is more easily confused with congenital lesions, especially with simple pulmonary stenosis. Pure beri-beri is rare in the United Kingdom, but is not uncommon in Japan, China, Java, and other eastern countries. The radiological appearances are similar to those of anoxic pulmonary heart disease, but there is no emphysema.

Hypoplasia of the pulmonary artery is characteristic of Fallot's tetralogy (fig. 2.47). There may be a distinct gap between the aortic knuckle and the curve of the left ventricle, and the vascular shadows at the hilum are reduced on both sides.

ENLARGEMENT OF THE RIGHT VENTRICLE

Right ventricular enlargement is more difficult to recognise than left. In the antero-posterior view there is usually some increase in the transverse and broad diameters, the right auricle being pushed a little to the right, and inter-ventricular septum to the left. In some cases the septum is so far the to the left that it forms the left border of the heart, only the tip of the left ventricle being visible from the front: the effect produced is that of increased angularity of the cardiac apex and a more acute left cardiophrenic angle, the general shape resembling the Dutch peasant's wooden shoe with turned-up toe. This is the "cœur en sabot", and is especially characteristic of Fallot's tetralogy (fig. 2.47)



Fig. 2.48—Right ventricular enlargement in a case of mitral stenosis (2nd oblique position)

In the left anterior oblique

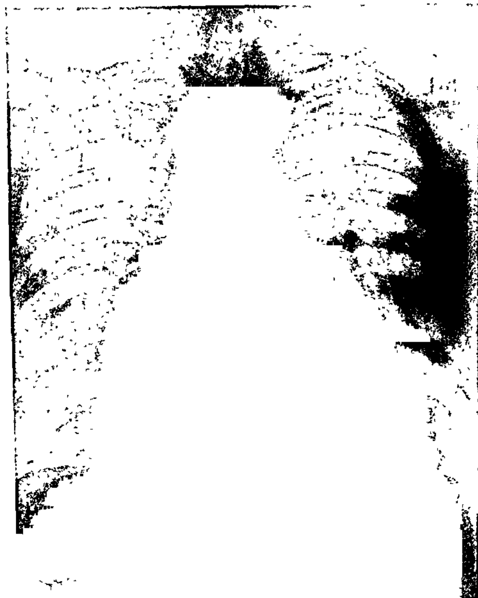


Fig 2 49—Gross enlargement of the right auricle due to tricuspid incompetence

position, right ventricular dominance is recognised by the increased curvature of the anterior border of the heart shadow Instead of the lob-sided appearance resulting from normal left ventricular bias, the heart shadow is more globular, the anterior and posterior ventricular curves being more equal (fig. 2 48). If the right auricle is enlarged, however, as may be determined from the antero-posterior view, interpretation is more difficult, for its shadow is superimposed on that of the right ventricle in the second oblique position, and it may be entirely responsible for the increased curvature of the anterior border.

The right ventricle is disproportionately enlarged in Fallot's tetralogy and in all conditions associated with dilatation of the pulmonary artery, except patent ductus and patent interventricular septum.

ENLARGEMENT OF THE RIGHT AURICLE

Dilatation of the right auricle, usually associated with fullness of the superior vena cava, is seen in most cases of congestive heart failure and of atrial septal defect, but it reaches gross proportions in tricuspid stenosis or incompetence and in Lutembacher's syndrome It may be distinguished from pericardial effusion by the blunt right cardiophrenic angle (cf. figs. 2 49 and 2 50).

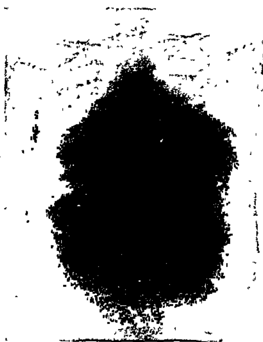


Fig 2 50—Pericardial effusion showing acute right cardiophrenic angle

When the shadow of a dilated left auricle appears on the right border of the heart, it should be recognised by its higher position and more abrupt curvature (fig 2 34). A zone of increased density is seen where it overlaps the shadow of the right auricle A grossly tortuous aorta occasionally gives rise to confusion, for its descending limb may appear to the right (fig 2.24) Fluoroscopy in the oblique positions should clarify the issue



Fig 2 51—General enlargement of the heart due to isolated myocarditis

GENERAL ENLARGEMENT OF THE HEART

General enlargement of the heart shadow, involving all diameters, is seen in rheumatic, diphtheritic, and Fiedler's carditis (fig. 2.51); in anæmia, thyrotoxicosis, arteriovenous aneurysm, and extensive active Paget's disease of bone; in myxœdema and sometimes in von Gierke's disease, in rheumatic heart disease with multiple valve lesions, and in fibrosis of the myocardium of uncertain etiology. An example of general enlargement due to thyrotoxic heart failure is shown in fig. 2.52.

PERICARDIAL EFFUSION

When effusion is considerable, the natural contours of the heart in the antero-posterior view are replaced by single bold curves, and pulsation is absent or greatly reduced. The right cardio-phrenic angle is unusually acute (fig. 2.50) In the first oblique position, the posterior border of the heart shadow may bulge beyond the barium-filled œsophagus When effusion is slight or moderate, however, radiological diagnosis may be difficult; for pulsation may be clearly visible, and may, indeed, be greater than that often seen in some of the conditions most likely to cause confusion. Moreover, the natural contours of the heart, on one or other border, may not be entirely lost, and may closely imitate the indefinite demarcations of the chambers which may be seen in acute carditis and myxœdema, for example. Under these circumstances more reliance should be placed on change of shape with alteration of posture, on bulging of the posterior inferior angle of the heart shadow in the first oblique position (instead of the normal concavity of the inferior vena cava), and on the degree and rapidity of changes in size from week to week.

CONSTRICTIVE PERICARDITIS

The most important radiological evidence of constrictive pericarditis is loss of pulsation without cardiac enlargement; but calcification of the pericardium is common and helpful, and is usually best seen in the left anterior oblique position (fig 2 53) Slight to moderate enlargement of the heart shadow may occur if the pericardium is sufficiently thick (1 to 2 cm), but the triangular appearance given by the obliquely set straight right and left borders should suggest the correct diagnosis (fig. 2.54)

CALCIFIED VALVES

Calcified valves are best seen fluoroscopically, they may be recorded by means of tomography. The patient should be turned 15 degrees to the left, and an imaginary line drawn from the point of opposing movement on the left border of the heart, downwards and to the patient's right, at an angle of 45 degrees with the horizontal (fig 2.55) The aortic valve is situated just above this line in the centre of the heart shadow, the mitral just below



Fig 2 52—General enlargement of the heart due to thyrotoxic heart failure with auricular fibrillation



Fig 2 53—Case of chronic constrictive pericarditis showing extensive calcification of the pericardium (2nd oblique position)



Fig. 2 54—Chronic constrictive pericari ing triangular shaped heart in the anter view.

it and a little to the patient's left. Calcification may be recognised by linear or anti-clockwise elliptical movement of dense crescentic opacities, in the direction of the anatomical axis of the heart, synchronous with the heart

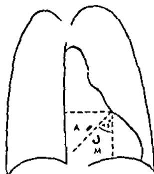


Fig 2 55—Orthodiagram showing the position of calcified valves The patient has been turned fifteen degrees to his left

A Aortic valve
M Mitral valve

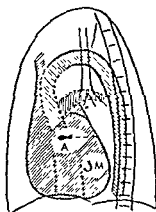


Fig 2 56—Orthodiagram showing the position of calcified valves in the 2nd oblique position

A Aortic valve
M Mitral valve

beat The technique requires proper accommodation and maximum constriction of the diaphragm so that only a square inch or so of the screen is visible. Calcified aortic valves are sometimes better seen in the second oblique position where they lie at the intersection of a vertical line through the centre of the heart shadow and a horizontal line through the top of the left ventricular arc (fig. 2 56). This view may be helpful in valve differentiation, for the mitral valve lies in the posterior third of the heart shadow (Sosman, 1939) and at a lower level

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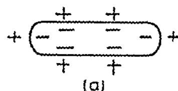
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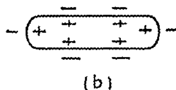
CHAPTER III

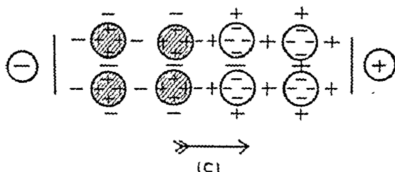
ELECTROCARDIOGRAPHY

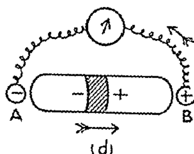
ELECTROCARDIOGRAPHY was discovered in relation to the frog's heart by Kolliker and Müller (1856), and was proved applicable to the study of the heart in man by Waller (1887), who used a capillary electrometer and an antero-posterior chest lead It was elaborated by Einthoven (1903), inventor of the string galvanometer and author of the famous triangle which bears his name, and used extensively by Lewis (1925) in his well-known researches on abnormalities of rhythm. In recent years many attempts have been made to place electrocardiography upon a more scientific and less empirical basis, and considerable success has been achieved in this respect, especially by Wilson and his colleagues (1930 *et seq.*). It is not easy (or necessary) for the ordinary physician, unless he also be a physicist and mathematician, to grasp the electrical details involved, but the following simplified account will be readily understood

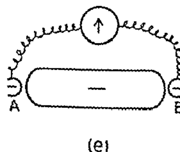
Certain molecules in the resting cardiac muscle cell dissociate into positive and negative ions The positively charged ions (cations) are distributed on the outer surface, the negatively charged ions (anions) within (Curtis and Cole, 1941). Such a cell is in a state of electrical balance and is said to be polarised (fig 3 01a). When the cell is excited its polarity is reversed, the negative charges coming to the surface, the positive charges passing within, and the cell is said to be depolarised (fig 3.01b) It should be clear that when a number of cells are clustered together, all in the resting polarised state or all in the excited depolarised state, there can be no potential differences anywhere on their collective surface If a group of cells were in the process of being excited, however, those already depolarised would possess negative surface charges, whereas those still polarised would have positive surface charges, and the collective surfaces of the two sets would yield a potential difference (fig 3 01c). This constitutes a doublet (Craib, 1930), dipole (Ashman, 1948), or double layer (Bayley, 1943) Thus, when an excitatory wave flows through cardiac muscle, its head is electrically positive and its tail negative (fig 3 01d) If electrodes are placed at A and B and connected to a galvanometer, an electrical current flows from B to A through the galvanometer, and from A to B through the tissue. The excitatory process, or accession wave as it is called, causes a very rapid or almost instantaneous reversal of cellular polarity, so that the duration of the galvanometric deflection is brief, and practically indicates the speed of the wave if the muscle thickness is known, or the muscle thickness if the speed of the wave is known When the impulse reaches B (fig. 3 01e) the whole muscle-block AB has a negative collective

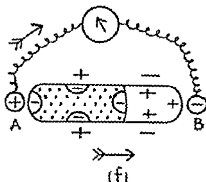












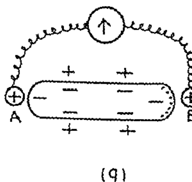


Fig 3 01—Accession and regression waves (stages of excitation and recovery) in cardiac muscles (see text)
(a) Resting polarised cell (b) Excited depolarised cell.
(c) Excitation proceeding through a group of cells
(d) Spread of the accession wave through a block of cardiac muscle.
(e) Muscle-block fully excited (depolarised)
(f) Spread of the regression wave or recovery process
(g) Muscle-block fully recovered (re-polarised)

surface, if recovery has not yet commenced at A, and there is no potential difference between A and B. Within a short time, however, recovery begins at A (fig. 3.01f), and the cells become repolarised, their collective surfaces becoming positively charged again. While the recovery process, or regression wave as it is called, is spreading from A towards B, a current again flows through the galvanometer, but in the opposite direction. The regression wave travels at the same speed as the accession wave, but causes a slower change of polarity, so that the galvanometric deflection is not so brief. If the movements of the galvanometer are graphically recorded, the passage of an excitatory impulse from A to B results therefore in a diphasic curve such as that shown in figure 3.02, the first deflection being quick or sharp, the second slow or blunt. Moreover, if the neuro-muscular tissue is uniform in all relevant respects, the area occupied by the first deflection, which may be measured by means of a planimeter with suitable magnification, is exactly equal, though of opposite sign, to the area occupied by the second deflection. In modern electrocardiographic parlance the first deflection is represented by the P wave when it reflects auricular excitation, and by the QRS complex when it reflects ventricular excitation, while the second is represented by the Ta and T waves respectively The QRS complex is written as the accession wave flows through the heart muscle from endocardial to epicardial surfaces; not as the excitatory impulse passes down the bundle of His, bundle branches and Purkinje network. As the heart is not a uniform muscle-block, but a bi-ventricular organ composed of numerous intertwining S-shaped muscle bundles (Robb and Robb, 1938), the initial ventricular deflection (QRS) is not monophasic, as in figure 3 02, but complex, and usually biphasic or triphasic, nor is the second ventricular deflection (T) of equal area and opposite sign. On account of this complexity, it is impossible, in the light of present knowledge, to determine by scientific theory precisely what an electrocardiogram should look like, it is only possible to find out by the practical method For this reason, electrocardiography has largely remained an empirical study

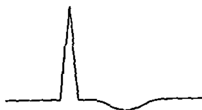


Fig 3 02—The diphasic curve produced by the processes of excitation and recovery in heart muscle

Einthoven's string galvanometer consists of an exceedingly fine fibre, such as silver-coated glass, suspended between the poles of an electro-magnet, when a current passes through the fibre, the latter is deflected towards one or other pole, according to the direction of the current By suitable magnification and illumination the movements of the shadow of this string may be recorded on a moving photographic film Valve-amplifying oscillographs of various forms, operated by potential differences, may be used instead of Einthoven's instrument Time-marking is so arranged that fine vertical lines appear on the film at intervals of

0.04–0.05 second, preferably with thicker lines every 0.20 second. Horizontal lines for measuring voltage are spaced at intervals of 1 mm.

Practical points to bear in mind include satisfactory insulation of the machine and lead-wires to prevent 50-cycle A.C. interference, proper standardisation of the galvanometer so that a deflection of 1 cm. represents a potential difference of 1 mv., and the elimination of skin resistance by means of electrode jelly. The paste described by Jenks and Graybiel (1935) has proved effective: it consists of sodium chloride 2950 G. (6.5 lb.), powdered pumice 3600 G. (8 lb.), gum tragacanth 226 G. (8 oz.), potassium bitartrate 114 G. (4 oz.), glycerol 710 ml. (24 oz.), phenol 28.5 G. (1 oz.), and water to 7.5 litres (2 gallons). The electrolytes are dissolved in one gallon of water, while the gum and glycerol are heated for six hours in the other, the two are then mixed, stirred, and reheated for one hour. Phenol and pumice (and more water if necessary) are then added, and mixed until the preparation has the consistency of cream. Fresh soft green soap (B.P.) is very little inferior, especially after rubbing the skin with some abrasive (Bell, Knox and Small, 1939). A number of satisfactory pastes or gels are marketed.

CHEST LEADS

Analys[illegible] grams has become simplified since the introduction o[illegible] 1934). Previously all electrocardiograms were bipolar, [illegible] tial differences between two electrodes placed at different sites on [illegible] rface of the body, each gathering different potential values. According to Einthoven's theory, however, the algebraic sum of the potentials at the left arm, right arm and left leg always equal zero, these points representing the apices of an equilateral triangle in the frontal plane of the body, the heart lying at its centre, and the limbs being regarded as extensions of the lead wires.* Thus it is only necessary to link up these three points to a common terminal (preferably through a resistance of 5,000 ohms in order to neutralise differences in skin resistance) to provide an electrode that remains at zero potential throughout the cardiac cycle. If this neutral or indifferent electrode is linked to one arm of the galvanometer, the instrument will record the potential variations of an "exploring" electrode linked to the other arm. This is the basis of all V leads, V standing for potential value or voltage at any particular point. It has been agreed that positivity of this exploring electrode should be represented by an upright electrocardiographic deflection.

It is now necessary to consider the variations in potential that may be recorded if the exploring electrode is placed over the surface of the left ventricle in man (Wilson *et al.*, 1944). As the accession wave spreads from endocardial to epicardial surfaces, the left ventricular cavity (in contact with the tail of the wave) becomes electrically negative, and the surface of the heart (in contact with the head of the wave) becomes electrically positive. The galvanometer therefore records an upright or positive deflection, R (fig. 3.03b). When the accession wave reaches the surface, the exploring

* The mathematical proof of this equation is given by Wilson *et al.* (1946), Goldberger (1947), and by others.

electrode undergoes an abrupt reversal of polarity, and the galvanometer registers a sharp downward deflection (the intrinsic deflection) As both the cavity and surface of the left ventricle are then at the same negative potential, the electrical field is abolished, and the galvanometer comes to rest (fig. 3 03c) A complication arises, however, because the accession wave starts at some point (such as the left side of the interventricular septum) remote from the muscle underlying the electrode The left ventricular cavity thus becomes negative before the muscle under the electrode

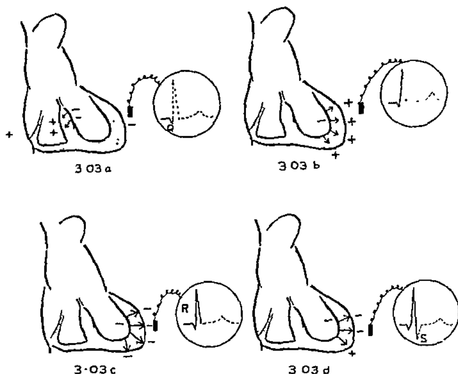


Fig 3 03—Formation of the Q, R and S waves (see text)

begins to be activated, and this negative potential is passively transmitted to the surface to be recorded as an initial downward deflection, Q (fig 3 03a) As leads taken from the right ventricular cavity show an initial positive deflection in practically all instances, it is now generally believed that the excitation wave starts on the left side of the septum Again, if the accession wave is still spreading through muscle remote from the exploring electrode when the galvanometer has registered the local intrinsic deflection, the electrical field is maintained, and continued negativity of the cavity is passively transmitted to the surface under the electrode, to be recorded as a final downward deflection, S (fig 3 03d)

When the exploring electrode is placed over the right ventricle, similar principles hold good; but the right ventricle is much thinner than the left,

and therefore the local potential differences are smaller and are normally overpowered by left ventricular events. An initial R wave is almost invariable and probably represents the positive potential produced in the right ventricular cavity as the accession wave spreads through the septum from left to right. Further development of R, as excitation passes through the anterior wall of the right ventricle, is more or less prevented by the stronger negative potential induced by the tail of the accession wave that is spreading through the left ventricle; this is represented by a large S wave. Q is never seen over a normal right ventricle The second ventricular deflection, T, is upright over the left ventricle, but may be inverted over the right (in leads V1 and V2).

In clinical electrocardiography multiple chest leads are designated leads V1–7. The figures indicate the position of the proximal electrode with reference to the chest-wall, and represent respectively the right and left borders of the sternum, the left para-sternal and mid-clavicular lines, and the anterior, mid, and posterior axillary lines, at the level of a line passing from the fourth intercostal space at points 1 and 2, to the fifth intercostal space at point 4, *and thence horizontally* (fig. 3.04). For routine purposes leads V1, V3 and V5, or V2, V4 and V6 are usually sufficient; but in particular instances other combinations or all seven leads are preferable. A typical record obtained with this technique is illustrated in fig. 3.05 Over the left ventricle (V5 and V6) there is a small Q wave, a large R wave, no S wave, an iso-potential R-T junction, and an upright T wave In the transition zone (V3–V4) Q has disappeared, a conspicuous S wave has developed, and T is sharply upright. Over the right ventricle (V1) there is again no Q wave, R is small, S large, and T is flattened In normal subjects the P wave is upright or occasionally diphasic (3 per cent) in V3, but often diphasic (20 per cent) or inverted (15 per cent) in V1. Q is usually present in V6, occurs in V5 in 45 per cent of cases, but is rarely seen farther to the right. S is usually absent in V6–7, is absent in V5 in 17 per cent of cases, but is invariably found in V3 and V1. T is always upright in V4–V6, may be occasionally diphasic in V3, and is inverted in V1 in 62 per cent of cases.

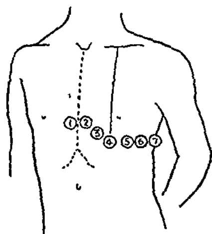


Fig 3.04—Multiple chest leads V1–V6. Position of the exploring electrode

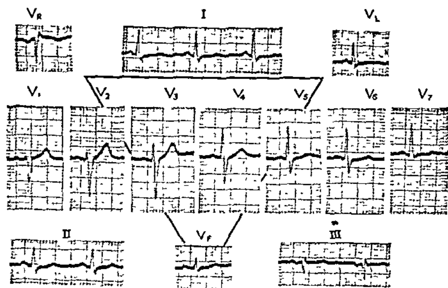
If there is clockwise rotation about the longitudinal axis (viewed from below), the anterior surface of the septum is shifted to the patient's left: this means that S is dominant in V4, the transition zone being shifted to V4 or V5 In such cases Q may not appear until V6 or V7. Similar graphs

V_R I V_L

V_1 V_2 V_3 V_4 V_5 V_6

II V_F III

(a) Average normal



(b) Clockwise rotation about longitudinal axis

Fig 3 05—Normal chest lead electrocardiogram (V1–V6)

V_R I V_L

V_1 V_2 V_3 V_4 V_5 V_6

II V_F III

Fig 3 05 (c)—Anti-clockwise rotation

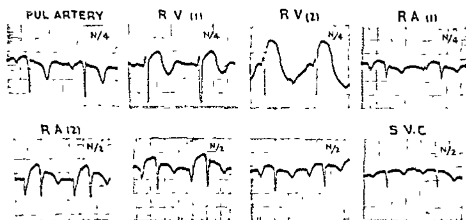


Fig. 3 06—Right ventricular and pulmonary artery cavity leads.

are obtained when the heart is horizontal in position, the septum then being displaced to the patient's left (fig. 3.05b)

Anticlockwise rotation about the longitudinal axis brings the anterior surface of the septum to the patient's right. The QR pattern may then be seen from V6 to V3, and the transition zone is shifted to V2 (fig 3 05c)

In addition to leads V1–V7, other positions of the exploring electrode have been used with advantage under exceptional circumstances An œsophageal lead may also be helpful in doubtful cases of posterior myocardial infarction, and an intracardiac lead may provide interesting information; but these are rarely necessary for clinical purposes.

The œsophageal lead takes its potential from the surface of the left auricle when high, and from the posterior surface of the left ventricle when low Left auricular potentials are transmitted from the cavity of the left ventricle, and show monophasic Q waves and inverted T waves, the cavity of the left ventricle being negative throughout the inscription of the initial and second ventricular deflections. The posterior surface of the left ventricle gives rise to a QR complex similar to that obtained anteriorly or laterally. Œsophageal patterns therefore show monophasic Q waves or QR deflections, Q dominating when the electrode is relatively high up, R when the electrode is relatively low down. T is usually negative when the electrode is high, positive when low.

Intracardiac leads from the cavity of the right ventricle show a small initial R wave followed by a deep S wave as already described If the catheter is passed through a patent foramen ovale into the left ventricle, a monophasic Q wave is obtained When the catheter is passed into the pulmonary artery, the small R wave seen within the cavity of the right ventricle disappears in favour of a monophasic Q wave (fig 3 06); this is because the pulmonary artery takes its potentials from the surface of the left auricle

There are thus only a limited number of basic QRS patterns upon which all ventricular deflections encountered in clinical electrocardiography depend (fig 3 07): the QR complex of a left ventricular surface lead (T normally upright), the RS complex of a right ventricular surface lead (T usually upright), the monophasic Q wave of a left ventricular cavity lead (T normally inverted), the RS complex of a right ventricular cavity lead (T normally inverted), and the balanced QR pattern of a combined left ventricular cavity and surface lead from the back of the heart (Goldberger, 1947)

The direction of the second ventricular deflection, T, is opposite to theoretical prediction in all the basic patterns, and suggests that the recovery wave starts at the surface of the ventricles and is directed towards the cavities.

Instead of V leads, many workers, including Wolferth and Wood (1932–33) who re-introduced chest leads to clinical electrocardiography, have coupled the exploring electrode with a relatively indifferent electrode

placed on the right arm (CR) or on the left leg (CF). Agreement will never be reached as to which of these is the more informative and it is expected that they will both be abandoned in favour of V leads. They will be considered in greater detail in subsequent paragraphs.

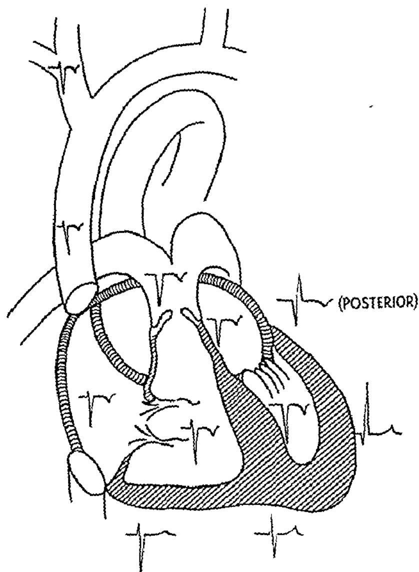


Fig 3 07—The basic QRS-T patterns

UNIPOLAR LIMB LEADS

The potential values in the right arm (VR), left arm (VL), and left leg (VF), may be obtained by placing the exploring electrode on the desired limb and linking it with Wilson's neutral electrode. As unipolar limb leads are of low voltage, it is customary to alter the standardisation so that a

potential difference of 1 millivolt causes a deflection of 15 mm (instead of 10 mm.) Alternatively, Goldberger's augmented leads may be used. With this technique the V lead is attached to the limb, the potential values of which are being measured, whilst the wire connecting this limb with the

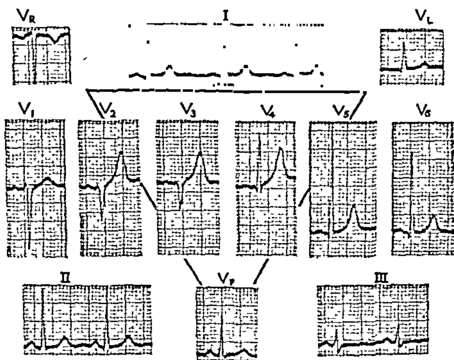


Fig 3 08*—Unipolar limb leads (VL, VR, VF) and standard leads 1, 2, and 3
(a) Normal (the heart is more horizontal than vertical)

central neutral terminal is detached and left hanging free. The potentials are thus increased by 50 per cent (Goldberger, 1942), thus.

$$\text{assuming } VR+VL+VF = 0$$
$$\text{then } VL+VF = -VR$$

Now when an electrode on the right arm is paired with a central terminal linked to the left arm and left leg, the galvanometer records $VR-\frac{VL+VF}{2}$, the latter being the mean potentials of the left arm and left leg

$$\text{Now} \quad VR-\frac{VL+VF}{2}$$
$$= VR-\frac{(-VR)}{(2)}$$
$$= VR+\tfrac{1}{2}VR = 1\tfrac{1}{2}VR$$

* The reduction in the voltage of R from V1 to V3 is due to the resistance of breast tissue, and is not uncommon in women

Fig 3 08 (b)—Horizontal heart

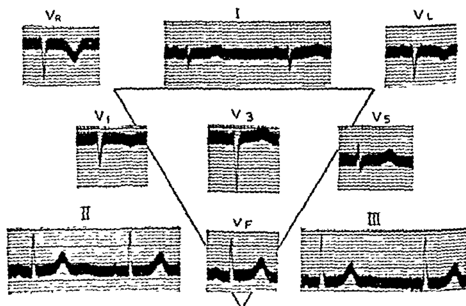


Fig 3 08 (c)—Vertical heart.

Unipolar limb leads are useful in determining the electrical position of the heart, in explaining the difference between CR, CF, and V chest leads, and in demonstrating the basis of the standard leads VR usually shows inversion of all complexes because it reflects the negative potential of the cardiac cavities transmitted through the great vessels (figs. 3.07 and 3.08). When the heart is normal in size and position, VL and VF are mainly positive, dominant left ventricular surface potentials being transmitted more or less equally to both of them; but VF is more positive than VL, because the latter is also influenced by the negative potentials of the cavities transmitted through the great vessels (fig. 3.08a). When the heart is electrically horizontal, however, left ventricular surface potentials are transmitted more strongly to the left arm, and right ventricular surface potentials to the left leg. There is then a small Q and tall R wave in lead VL, and a small R and deep S wave in lead VF (fig. 3.08b) When the heart is electrically vertical, the negative potentials of the cavities are transmitted more strongly to the left arm, and the left ventricular surface potentials more strongly to the left leg There is then a small R and deep S wave in VL, and a small Q and tall R wave in VF (fig 3.08c)

The differences between CR, CF and V chest leads may now be appreciated: CR leads are V leads minus the potentials in VR, whilst CF leads are V leads minus the potentials in VF. As VR potentials are negative, their subtraction from V in CR records makes all deflections more positive – not only is R taller in lead CR1, but T is invariably upright in adults and in children over eight years of age Again, since VF potentials are normally positive, their subtraction from V in CF records makes all deflections more negative As the voltage is usually higher in VR than in VF, however, CR leads show greater differences from V leads than do CF leads

STANDARD LEADS

Einthoven's bipolar leads, introduced at the beginning of the century and adopted as the standard leads throughout the world, consist of the left and right arm (lead 1), the left leg and the right arm (lead 2), and the left leg and left arm (lead 3) Electrocardiograms derived from these leads can be calculated, of course, from the deflections obtained with unipolar limb leads; for lead 1 equals VL–VR, lead 2 equals VF–VR, lead 3 equals VF–VL. The subtraction of the negative potentials in VR from the positive potentials in VL result in strongly positive QRS and T deflections Again, as the voltage of R in VF is usually higher than that in VL, QRS is also normally positive in lead 3

By definition there is an obvious relationship between the three standard leads·

$$\text{lead } 2 = \text{lead } 1 + \text{lead } 3$$

This merely states that

$$\begin{aligned} VF-VR \text{ (lead 2)} &= \not{VL}-VR \text{ (lead 1)} + VF-\not{VL} \text{ (lead 3)} \\ &= VF-VR. \end{aligned}$$

and has nothing to do with Einthoven's theory or triangle

The relationship between the standard leads and the Wilson unipolar limb leads is as follows:

$$VL = \frac{I-III}{3}$$

$$VR = \frac{I+II}{3}$$

$$VF = \frac{II+III}{3}$$

The augmented values obtained with Goldberger's technique may be derived from the standard leads by changing the denominator in the above equations from 3 to 2.

NORMAL APPEARANCES

(Fig. 3.08)

P wave P represents *the excitation process as it spreads from the sino-auricular node through both auricles. It is usually blunt, and is upright in* leads 1 and 2, but may be inverted in lead 3 Its height should not exceed 2 0 mm, and its duration 0 1 second. Following P, slight depression of the base-line, sometimes hidden by the QRS complex, may be evident, and represents auricular recovery or repolarisation It has been termed the auricular T wave or Ta wave.

P–R interval. No deflection is caused by the passage of the excitatory impulse down the bundle of His, its main branches, and Purkinje network, so that there is an iso-potential interval between auricular and ventricular events. this is the P–R interval, and is conveniently measured from the beginning of P to the beginning of QRS. It commonly ranges between 0.12 and 0.20 second, but occasionally, even in young subjects, it may measure 0 21 or 0 22 second, without evidence of heart disease or of general ill health

The P–R interval is little affected by spontaneous variations in heart rate, but may be slightly reduced by atropine, and slightly lengthened by carotid sinus compression Vagal tone has a much greater effect on the sinus node than on A–V conduction.

The QRS complex. Q, R, and S, when all are present, form a triphasic complex representing the spread of the accession wave through the ventricles, and are convenient symbols for describing the shape of the initial ventricular deflection. Each is applied to a wave so defined by its direction and by its time-relationship to the others Thus any upward deflection is called R, or if there are two such, R and R1. A downward deflection is called Q if it precedes R, or if it is the only wave present, and S if it follows R.

Q rarely measures more than 1 or 2 mm. in leads 1 and 2, and is often absent altogether; in lead 3, however, it may be conspicuous, and may

measure up to one-third of the amplitude of R. R should exceed 5 mm in height in the most favourable lead, unless the spatial vector is unusually postero-anterior. Slight notching or slurring near its base is common and has no significance. Distortion of the apex of R is rare in normal subjects, but may be disregarded when unaccompanied by other changes S is variable, and is greatly influenced by axis deviation, which will be considered later.

The whole QRS complex should not exceed 0 1 second in duration, and rarely exceeds 0 08 second in normal individuals

RS–T segment. This refers to that short segment between the QRS complex and the T wave, i.e. between the end of the excitatory and the beginning of the recovery processes. In some cases this is so short as to represent merely the RS–T junction. Any deviation of the RS–T segment from the iso-potential base-line should be regarded with suspicion. Slight deviation, of the order of 0.5 mm., may be within normal limits, yet taken in conjunction with other findings may be highly significant

It is customary to include the proximal portion of the T wave when describing the shape of the RS–T segment, e.g whether concave, straight, or convex. Speaking in this way, a normal RS–T segment curves gently from its point of origin in the direction of the T wave; it is neither straight, nor does it deviate in the opposite direction first.

T wave. T represents the recovery process or the regression wave (repolarisation), and is known as the second ventricular deflection. It is normally upright in leads 1 and 2, but may be inverted in lead 3 It should measure at least 2 mm in amplitude in the most favourable lead.

Q–T interval The interval between the beginning of QRS and the end of T represents the total time occupied by ventricular excitation and recovery. It is inversely proportional to the heart rate, ranging between 0 42 second at a speed of 48 per minute, and 0 28 second at a speed of 110. The formula of Bazett (1920) is $Q–T=K\sqrt{C}$, where C represents the cycle length. The constant K is variously given as 0.38—0 39 plus or minus 0 04, and is a trifle longer in women than in men and children.

Taran and Szilagyi (1947) have made the sensible suggestion that the Q–T interval should be recorded as corrected for rate, i e as $Q–T_c$ This should equal Bazett's constant, K, i e. the actual Q–T interval when the heart rate is 60 per minute or when the cycle length is one second $Q–T_c$ is easily calculated with the aid of a slide rule when the actual Q–T interval and cycle length are known; for $Q–T_c$ (or K)$=\frac{Q–T}{\sqrt{C}}$ The Q–T interval is lengthened by hypocalcæmia (fig 3 33) and shortened by digitalis. Prolongation of $Q–T_c$ provides valuable evidence of active rheumatic carditis (page 271). There is some evidence that $Q–T_c$ is also lengthened by cardiac enlargement from any cause, and shortened by cardiac compression as in pericardial effusion (Van Lingen, 1947)

U wave. Following T, and coinciding with the super-normal recovery

phase, a small, rounded, positive deflection, the U wave, may be seen. Its significance is not fully understood; but it appears to be exaggerated in chest leads taken from the right of the interventricular septum and to be flattened or even inverted in leads taken from the left of the septum when there is left ventricular hypertrophy, and the opposite when there is right ventricular hypertrophy It may also be inverted in left ventricular surface leads during an attack of angina pectoris. It is accentuated by digitalis.

THE CARDIAC VECTOR

Maximum potential differences within the heart at any given moment may be represented in magnitude and direction by a line of appropriate length and spatial direction (drawn from the hypothetical centre of electrical events), which may be called a vector, and its direction a spatial axis Both magnitude and direction of this vector alter from moment to moment during the phases of ventricular excitation and recovery, but may be

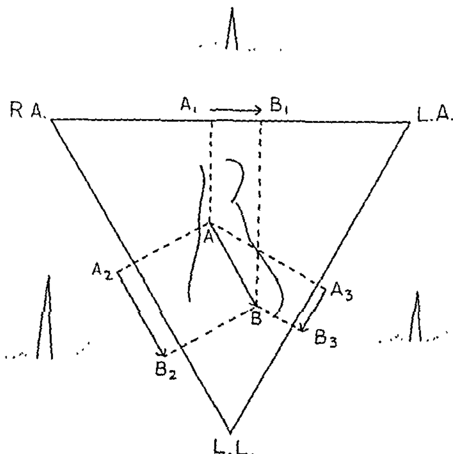


Fig 3 09—Projection of the frontal plane QRS vector on to the sides of Einthoven's equilateral triangle.

resolved into mean values. If such a vector is projected on to the frontal plane of the body, its new momentary or mean manifest value may be calculated by suitable measurements, detailed below, of the electrocardiograms obtained from any two of Einthoven's leads: for the frontal plane or manifest vector may be projected on to the sides of an equilateral triangle, the apices of which are represented by the left and right arms (or shoulders) and by the left leg (or symphysis pubis), the sides of the triangle thus representing the three standard leads. For example, if the line AB (fig. 3.09) represents the maximum momentary manifest QRS vector, i e if it represents the projection on to the frontal plane of the body of a line in space representing the magnitude and direction of maximum potential differences generated within the heart during the period of ventricular excitation, then the lines A1–B1, A2–B2, and A3–B3, obtained by projecting the line AB on to the sides of Einthoven's equilateral triangle, give the magnitude and direction of the maximum QRS deflection in leads 1, 2 and 3 respectively. Moreover, it can be easily shown that, at any given moment, the amplitude of the QRS deflection in lead 2 equals the algebraic sum of that in leads 1 and 3; or the amplitude of the QRS deflection in any one lead, equals the algebraic sum of that in the other two The same law applies to auricular activity and to the recovery phase, i e to the P, Ta, and T waves, and to mean as well as momentary values Conversely, if the magnitude and direction of the QRS complex at any given moment is known in any two leads, their resultant drawn from the centre of Einthoven's triangle represents the manifest (frontal plane) vector of QRS at that particular moment, and its direction the manifest electrical axis In current electrocardiographic nomenclature, the electrical axis refers to this resultant frontal plane axis as obtained from the maximum upright QRS deflection in any two leads, usually R1 and R2, if apparently synchronous, and is expressed in terms of its angle with the horizontal, being plus when rotated clockwise from this base, minus when anti-clockwise As so expressed, the normal electrical axis lies between 0 and 90 degrees, and has a wider range than the frontal plane anatomical axis

Triaxial reference system For convenience Einthoven's triangle may be suitably represented as a triaxial reference system (Bayley, 1943) The lines representing the three sides of the triangle are transposed so that they intersect at a common point, O (fig 3 10) The horizontal line RL then represents lead 1, and the lines RF and LF leads 2 and 3 respectively The customary signs are preserved so that R is negative, F positive, and L negative or positive as shown in the diagram If the vector, OA, is projected on to these lines, its value in the standard leads may at once be determined by the lengths OA1, OA2 and OA3. The converse may be applied with equal simplicity.

By measuring the net area of QRS in any two leads (instead of momentary synchronous points) by means of a planimeter and suitable magnification (or by dividing the amplitude of the wave by half its width), the area

below the base-line being subtracted from that above, the resultant mean axis of QRS in the frontal plane can be determined in similar fashion (Wilson *et al.*, 1934). Measurements may be made in millivolt-seconds, microvolt-seconds, or in suitable units based on voltage × time (Ashman and Byer, 1943) Such a resultant, drawn from the centre of Einthoven's triangle, having both magnitude and direction, is called the mean QRS vector in the frontal plane, or the manifest mean QRS vector, and its direction the manifest mean QRS axis. Manifest mean vectors for T and P may be similarly obtained. Bayley (1943) has suggested that the symbol

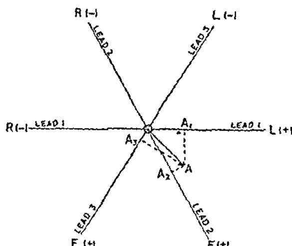


Fig 3 10—Bayley's triaxial reference system

$\hat{A}$ might well designate the axis of such vectors, and the symbol A their magnitude: the manifest mean axis of QRS would then be called $\hat{A}_{QRS}$, and its magnitude A_{QRS}.

If the heart were a simple uniform muscle-block, the algebraic net area occupied by QRS and T would be zero, as it is not, the net area of QRST has a positive or negative value, which if measured in any two leads may be resolved into a vector drawn from the centre of Einthoven's triangle. The axis of this vector, or the man[illegible] QRST [illegible] has been

of maximum local variations in the speed of the processes of excitation and recovery, whereby the heart differs from a uniform muscle-block

The manifest mean axis of QRS averages about 60 degrees, that of T about 50 degrees. The ventricular gradient in hearts which are not anatomically rotated ranges between 45 and 65 degrees On the whole, hearts which are relatively central in position, i.e rotated clockwise (viewed from the front) about their antero-posterior anatomical axis, are also rotated clockwise (viewed from the apex) about their longitudinal anatomical axis, and show clockwise deviation, i.e. deviation to the right, of all manifest momen-

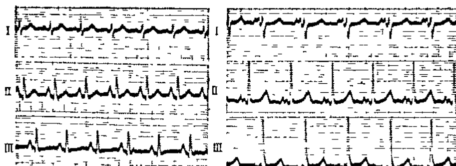
tary and mean electrical axes; but the greatest shift occurs with the ordinary momentary electrical axis of QRS, and the least with the ventricular gradient. This also applies to transverse hearts with anti-clockwise rotation and deviation of all electrical axes to the left (Ashman and Byer, 1943)

From what has been said it should be clear that the QRS and T vectors in the frontal plane of the body alter in magnitude and direction from moment to moment during the phases of ventricular excitation and recovery respectively. As one end of such a vector is fixed at the centre of Einthoven's triangle, it follows that the other end must describe a continuous curve. Mann (1920) showed how such curves could be reconstructed, and later devised a method of recording them directly (1931) More recently, Wilson and Johnston (1938), employing the cathode-ray oscillograph, published typical curves, and called them vectorcardiograms Even these, however, are restricted to the behaviour of the vector in the frontal plane of the body, being so limited by use of the standard limb leads.

ELECTROCARDIOGRAPHIC ABNORMALITIES

ABNORMALITIES OF THE P WAVE

There are four main varieties of P wave deformity: the tall sharp P wave of right auricular hypertrophy (fig 3.11a), the conspicuous widened P wave of left auricular hypertrophy, which may be bifid, rounded, or flat-topped



(a) Right auricular hypertrophy (b) Left auricular hypertrophy

Fig 3 11—Abnormal P waves

(fig 3 11b); the low-voltage widened P wave, which may be also bifid, rounded, or flat-topped (fig. 3.11c), and the inverted P wave (fig 3 11d)

Tall sharp P waves are characteristic of tricuspid stenosis, chronic pulmonary heart disease, and congenital pulmonary stenosis The voltage ranges between 2 and 5 mm , and as the wave is not widened, it becomes peculiarly sharp, like an arrowhead Similar P waves are sometimes seen in mitral stenosis, thyrotoxicosis, massive pulmonary embolism, asthma, and pneumonia. They are usually most evident in leads 2 and 3

Conspicuous widened P waves, measuring 0.12 second in duration, are almost diagnostic of mitral stenosis. The voltage usually approaches 2.5 mm, but rarely exceeds it. Many examples are bifid, but others are blunt or flat-topped. They are usually seen best in leads 1, 2 and V_5

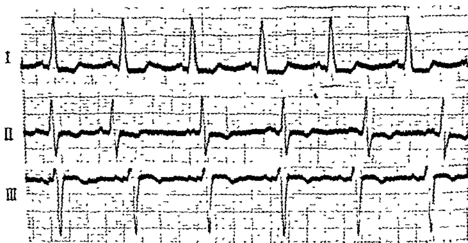


Fig 3 11 (c)—Hypertensive low voltage

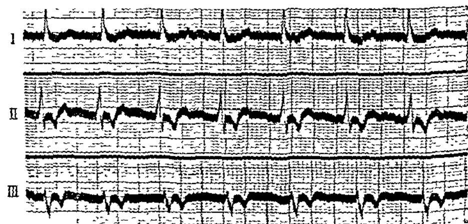


Fig 3 11 (d)—Inverted (nodal)

P waves similar in shape and *width*, but usually of lower voltage, may be seen sometimes in advanced cases of hypertensive heart disease or of aortic valve disease. It is uncertain whether they represent left auricular dilatation due to left ventricular failure, as originally suggested by Wood and Selzer (1939), or inter-atrial block (Berconsky and Kloztman, 1945).

Inverted P waves are found in lead 1 in cases of dextrocardia, and in all leads in many cases of nodal rhythm. Occasionally *P is inverted* in leads 2 and 3 without obvious cause.

ABNORMALITIES OF THE QRS COMPLEX

Axis deviation. It has already been pointed out (page 81) that the electrical axis of the heart refers to the frontal plane projection of the maximum momentary spatial vector, and usually lies between 0 and 90 degrees, more or less in the anatomical axis. Anti-clockwise rotation of the

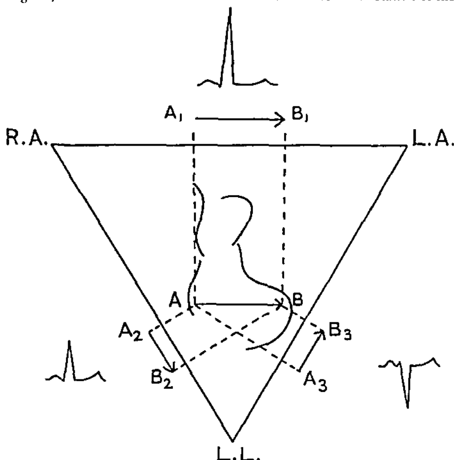


Fig. 3 12—Left axis deviation (Einthoven's triangle)

heart about its antero-posterior axis (viewed from the front), or about its longitudinal axis (viewed from the cardiac apex), causes deviation of the electrical axis to the left, so that the frontal plane vector may make a minus angle with the horizontal, whilst clockwise rotation about similar axes causes right axis deviation, the vector now making an angle of more than 90 degrees with the horizontal Left or right axis deviation respectively also occurs when the left or right ventricle is disproportionately enlarged. Moreover, left ventricular enlargement is often associated with anti-clockwise rotation about both anatomical axes, and right ventricular enlargement with clockwise rotation

Reference to Einthoven's triangle will show that if the electrical axis deviates to the left, and approaches or surpasses the horizontal, lead 1 becomes the axial lead (fig. 3 12) R_1 then carries the maximum voltage, R_2 is smaller, and the maximum QRS deflection in lead 3 is downwards, i e the main deflection is S In such cases S_3 is really the electrical counterpart of R_1. Unipolar limb leads commonly show an electrically horizontal heart, R in VL and S in VF being unusually conspicuous.

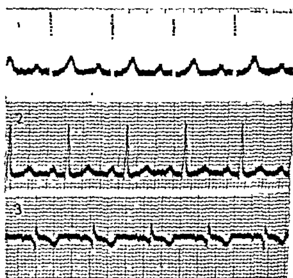


FIG 3 13—Axis deviation due to elevation of the diaphragm (Q3 S1 type)

Left axis deviation occurs in 10 per cent of normal individuals, in any condition in which the left ventricle is disproportionately enlarged, in cardiac displacement to the left from scoliosis or from intrathoracic causes, and when the diaphragm is elevated causing the heart to lie more transversely It may not be possible from examination of the limb lead QRS complexes alone to decide whether axis deviation is due to displacement or to left ventricular preponderance, but this distinction may often be made by considering the behaviour of the RS-T segment and T wave, and especially by noting the QRS pattern in multiple chest leads (*vide infra*)

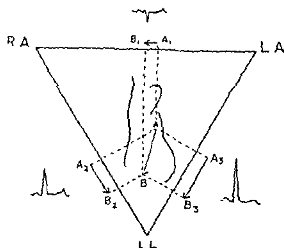


FIG 3.14—Right axis deviation (Einthoven's triangle)

A particular form of axis deviation is seen with elevation of the diaphragm, as from obesity, pregnancy, flatulence or ascites. R_1 is taller than R_2, S_1 and Q_3 are prominent, and T_3 is inverted (fig. 3.13). In such cases there is no Q wave in lead VF, and the T wave usually remains inverted in lead V1.

When the electrical axis is deviated to the right, so that it occupies a more or less vertical position, lead 3 becomes the axial lead (fig 3.14). R_3 then carries the maximum voltage, R_2 is smaller, whilst the maximum deflection in lead 1 is S, which is the electrical counterpart of R_3. In unipolar limb leads S is conspicuous in VL and R in VF. Right axis deviation is the rule in newly born infants, is common in very young children, occurs in 1 per cent of normal children over the age of eight, and is rarely seen in

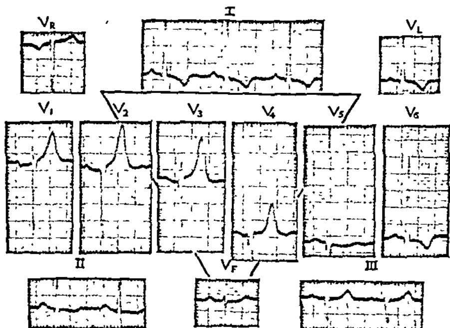


Fig. 3 15—Left ventricular preponderance (heart horizontal).

strictly normal adults, It may be caused by appropriate cardiac displacement or rotation, and by right ventricular dominance. As with left axis deviation, it may not be possible from inspection of the limb lead QRS complexes alone to determine whether the axis shift is due to right ventricular dominance or otherwise; but the behaviour of QRS in multiple chest leads may clarify the issue (*vide infra*)

Left ventricular preponderance. When the left ventricle is enlarged, the accession wave takes longer to penetrate that chamber and creates more powerful potential differences Thus R in leads V5 and V6 and S in leads V1 and V2 have a larger amplitude (R in V4, 5, or 6 > 25 mm., S in V1 > 15 mm.), the intrinsic deflection in left ventricular surface leads is delayed (longer than 0.05 second), and the width of QRS slightly increased (0.1 to 0 12 second). In addition, the transition zone is usually shifted to the left, the heart being horizontal, and R is found to be exceptionally small in leads V1 and V2. Secondary changes in the T wave occur in advanced cases, the

R-T segment being depressed and T inverted in leads V5 and V6, and the S-T segment being elevated and T sharply upright in leads V1 and V2 (fig. 3.15).

When the heart is horizontal, which is usual, VL resembles V5, and VF resembles V1 *both in respect of* QRS and T. The appearances in standard lead 1 therefore also resemble V5 or V6, and those in lead 3 resemble V1.

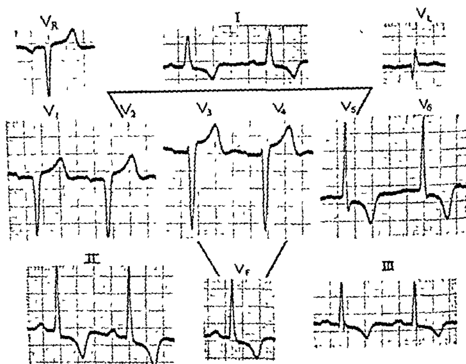


Fig. 3.16—Left ventricular preponderance (heart semi-vertical)

When the heart is more or less vertical, which is less common, left ventri-*cular surface potentials are transmitted more to the left leg*. There is then no axis deviation in standard leads (Wilson, 1944), but high voltage and perhaps T wave inversion in all (fig. 3.16). Concordant left ventricular preponderance, as it is called, is best seen in concentric left ventricular hypertrophy, such as may occur in aortic stenosis and malignant hyper-tension.

Right ventricular dominance. When there is gross enlargement of the right ventricle the potential differences generated by the wall of that chamber may approach or even surpass those from the left ventricle. Right ventri-cular surface leads may then truly represent the outward spread of the accession wave beneath the exploring electrode. R is therefore taller than usual in V1 and may be the chief ventricular deflection; at the same time the intrinsic deflection is delayed, and S is conspicuous in V5 and V6 (fig

3 17). Secondary inversion of the T wave with slight depression of the R-T segment is common in V1 to V3 In lesser degrees of right ventricular hypertrophy, insufficient to account for such a pattern, clockwise rotation about the longitudinal axis (viewed from below) is usually held responsible for the changes. Thus the occasional appearance of Q in lead V1 may be derived from potentials at the back of the heart.

As a rule the heart is also vertical in position, VL is strongly influenced by negative cavity potentials, and VF by left or right ventricular surface

Fig 3 17—Right ventricular dominance (case of mitral stenosis receiving digitalis).

potentials. In other words, QRS is mainly negative in VL and strongly positive in VF. Standard leads therefore show right axis deviation, and there may be inversion of the T wave with depression of the R-T segment in lead 3, or in leads 2 and 3 When R is dominant in V1, and S in V5, right axis deviation also occurs when the heart is horizontal, for VL then reflects V5, and VF reflects V1.

Widening of the QRS complex The accepted maximum normal limit of 0.1 second for the duration of the QRS complex is generous, and includes many instances of abnormal widening due to increased thickness of the ventricular walls As the accession wave causes almost instantaneous reversal of polarity in the tissue it excites, the width of QRS depends almost entirely on the thickness of the ventricular walls, provided the conducting system is normal, and assuming that the speed of the wave is constant. With extremely hypertrophied hearts it is theoretically possible for QRS to measure as much as 0 12 second in duration; but in fact it rarely exceeds 0.1 second. It is probably wise to regard anything over 0 11 second as intraventricular block. It is found, too, that widening due to ventricular

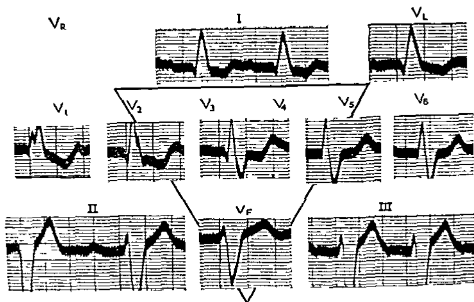
hypertrophy is usually associated with high voltage, whereas in bundle branch block QRS is commonly notched, splintered, or heavily slurred. When the heart is grossly dilated, there may be some delay in the passage of the excitatory impulse down the Purkinje network, causing intraventricular block. Some such mechanism may account for the transient right "bundle branch block" that occurs occasionally in massive pulmonary embolism, and for the right "bundle branch block" so commonly seen with atrial septal defect. A Q wave can nearly always be demonstrated in suitable left ventricular surface leads when widening of the initial ventricular deflection is due to left ventricular hypertrophy, whereas it is ordinarily absent in left bundle branch block.

Widening of the QRS complex is also seen in uræmia, when it is due to a raised blood potassium (figs 3 33 and 3 34).

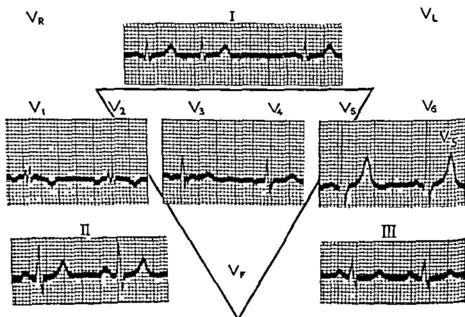
Bundle branch block. In *left bundle branch block* the excitatory process spreads through the right ventricle in normal fashion but does not at first reach the left ventricle As the interventricular septum is excited from the right side, the accession wave spreads through it from right to left. The cavity of the left ventricle therefore becomes initially positive, and this potential is transmitted passively to the surface as an R wave in V5 or V6. There can be no Q wave in such leads with a healthy septum When the accession wave reaches the left side of the septum there is an immediate reversal of polarity, the left ventricular cavity becoming momentarily negative This negativity is again transmitted passively to the surface, V5 showing a momentary downward deflection following the initial R wave. Almost immediately, however, the excitatory process spreads throughout the endocardium of the left ventricle, and the accession wave begins to flow outwards in the usual way The surface of the left ventricle then becomes actively positive and the true R wave is written When the surface is activated the final intrinsic downward deflection occurs V5 or V6 thus exhibits a large widened R wave interrupted by a relatively early notch representing the arrival of the accession wave at the left side of the septum (fig. 3.18) Right ventricular surface potentials are influenced at first by a normal right ventricular accession wave and later by the delayed negativity of the cavity of the left ventricle which is passively transmitted through the depolarised septum and right ventricle. Thus V1-V3 exhibit small R waves, early intrinsic deflections and deep wide S waves. The total duration of QRS commonly measures 0.12 to 0 16 second. As the heart is usually horizontal the V5–V6 pattern is seen also in VL and lead 1, and the V1 pattern in VF and lead 3 Should the heart be more or less vertical, however, the V5-V6 pattern is transmitted to the left leg, and QRS may be mainly upright in all standard leads as in concordant left ventricular preponderance. The T wave is secondarily deformed and the RS-T segment deviated from the base line in all leads, and are commonly of opposite sign to the QRS complex Thus, with horizontal hearts the RS-T segment is depressed and the T wave inverted in V5-V6, VL, and standard lead 1.

Fig 3 18—Left bundle branch block (heart horizontal)

3 19—Right bundle branch block (usual appearances).



(a) Associated with a vertical heart



(b) Partial, seen clearly only in chest leads

Fig 3 20—Right bundle branch block

In *right bundle branch block* the septum is activated entirely from the left side. The potential of the right ventricular cavity is therefore initially positive, and is passively transmitted to the surface where it may be recorded as the first part of R. When the accession wave reaches the right side of the septum, the polarity is abruptly reversed, and a pseudo-intrinsic deflection is recorded at the surface. Almost at once, however, the right ventricular wall is invaded, and the surface then becomes actively positive. This results in a second R wave and finally in the true intrinsic deflection. Leads V1 and V2 therefore show a widened notched R wave, or a large M complex. T is in the opposite direction (fig. 3.19). Over the left ventricle in leads V5 and V6 normal QR wave and intrinsic deflection are followed by a grossly slurred S wave representing delayed negativity of the right ventricular cavity passively transmitted through the depolarised septum and left ventricle. As a rule V5 and V6 potentials are transmitted to VL and form the pattern of standard lead 1; the M complex of V1–V2 is usually seen in VF and in standard lead 3. When the heart is vertical, however, V1 potentials may be transmitted to VL, and standard leads may look like left bundle branch block (fig. 3.20a) Multiple chest leads may be necessary, not only to determine which bundle branch is blocked, but also to detect the lesion at all in some cases: partial right bundle branch block, for instance, is frequently overlooked in standard leads (fig. 3 20b)

ABNORMALITIES OF THE RS-T SEGMENT AND T WAVE

It is profitable to consider the RS-T segment and T wave together, and in many cases to consider them also in relationship to the QRS complex, for they are all ventricular events. The various patterns made up by these three variables in limb and multiple chest leads provide a wealth of information concerning the state of the ventricles in health and disease Secondary inversion of the T wave in relation to QRS changes has already been described

Myocardial infarction. It is customary to describe two types of electrocardiogram associated with myocardial infarction, T_1 and T_3 types (Parkinson and Bedford, 1927), the first denoting anterior, the second posterior lesions (Barnes and Whitten, 1929). There is no essential difference in the shape of these two patterns, the difference depending upon the leads in which they are found

If an infarct involves the whole thickness of the muscle wall, no accession wave can flow through it The negative cavity potential produced by outward spread of the accession wave through remote healthy muscle is then passively transmitted through the infarct to the surface overlying it An electrode placed over the infarct therefore registers an initial negative deflection or Q wave If the infarct involves only the outer part of the muscle, the accession wave begins as usual, the surface potential is initially positive, and there can be no pathological Q wave, but when the accession wave reaches the infarct it can advance no farther, so R is reduced in

amplitude. In anterior left ventricular infarcts these QRS changes may be registered in leads V3, V4, V5 and V6, being more marked in V3–V4 in antero-septal infarcts, and in V5–V6 in antero-lateral infarcts. They are commonly transmitted to VL and are therefore seen well in standard lead 1 (fig 3.21). Similar QRS changes occur in posterior infarcts but are transmitted to VF and thus to standard lead 3 (fig. 3.22a). When the heart is vertical, however, typical changes in V5 from an anterior infarct may be transmitted to lead VF and hence to standard leads 2 and 3 (fig. 3.22b)

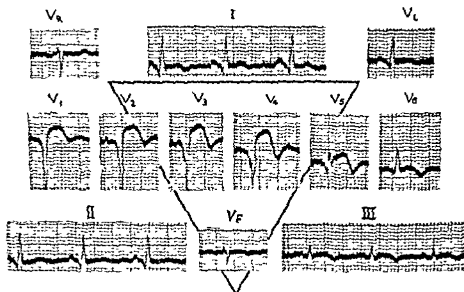


Fig 3 21—Anterior myocardial infarction showing pathological Q waves and elevation of the RS-T segment in leads V1–6, VL and standard limb lead 1.

Partly necrosed muscle sets up a steady current due to the development of potential differences between injured and healthy tissue. Injured tissue is electro-negative, healthy tissue is positive, and completely necrosed tissue electrically inert When the injured area involves the outer portion of the ventricular wall, the surface is therefore negative, the current flowing from without inwards (Wilson *et al*, 1933) An electrode placed over the infarct registers this negativity by depressing the base line. This is shown in the electrocardiogram (fig 3 21) by abrupt elevation of the base line when the current of injury is momentarily abolished by spread of the accession wave through the healthy tissue, for such activation causes the healthy tissue to take up a negative potential, and so abolishes the potential differences set up by the injury. In other words, a recent deep infarct associated with superficial injury results in elevation of the RS-T segment. In anterior infarcts this displacement is seen in leads V3–V6, and is commonly transmitted to VL and hence to standard lead 1 (fig. 3 21). In posterior infarcts

VR I VL

V1 V2 V3 V4 V5 V6

II VF III

Fig 3 22 (a)—Posterior myocardial infarction showing pathological Q waves and elevation of the RS-T segment in lead VF and standard limb lead 3

VR I VL

V1 V2 V3 V4 V5 V6

II VF III

Fig 3 22 (b)—Anterior infarction with vertical heart Standard leads show changes that simulate those of posterior infarction.

VR I VL

V1 V2 V3 V4 V5 V6

II VF III

(a) Anterior

VR I VL

V1 V2 V3 V4 V5 V6

II VF III

(b) Posterior

Fig. 3.23—Later stages of anterior (a), and posterior (b), infarction, showing typical Q waves and inversion of the T wave in appropriate leads.

it is seen in low œsophageal leads, in V7, and is transmitted to VF and hence to standard lead 3 (fig. 3.22a).

Pathological Q waves may be seen in acute cases within a few hours of the onset, and usually outlast all other evidence of infarction, often being permanent. Elevation of the RS-T segment also occurs early, but usually subsides within two or three weeks The shape of the segment is typical,

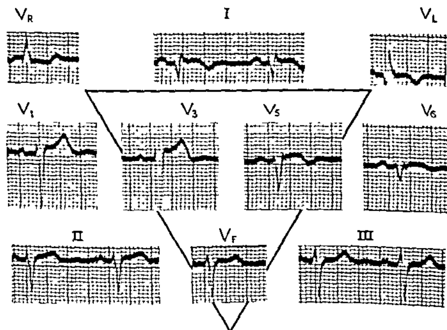
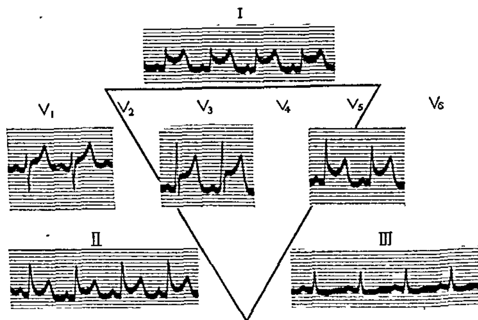


Fig 3 24—Anterior myocardial infarction showing an R wave which is smaller in V3 to V6 than in V1.

being straight instead of concave when elevated, and being convex or cove-shaped (Pardee, 1920) when the RS-T junction approaches or regains the iso-potential level. The T wave itself becomes inverted within a few days of the onset, often profoundly
the same time that the RS-T
(fig. 3.23 a and b) Further
rarely revert to normal

In T_1 patterns reciprocal effects are usually observed in lead 3, i e the RS-T segment may be depressed at first, and T may be sharply upright later. Again, in posterior infarcts early RS-T depression and later accentuation of the T wave may often be seen in lead 1 and in anterior chest leads. A helpful sign of old anterior infarction is an R wave in V1-V2 which is taller than that in V3-V4 (fig 3 24), especially when the appearances in V5-V6 are more or less normal. Finally, it is most important to understand that characteristic changes may be found in multiple chest



(a)—Early stage, showing elevation of the RS-T segment

I

V2

V4

V5

II

III

(b)—Late stage, showing inversion of the T wave in all leads

Fig. 3.25—Pericarditis

leads or in an œsophageal lead when the standard limb leads are normal, and that a single chest lead may be normal when others show diagnostic features.

Pericarditis. In all types of generalised pericardial disease, except hydropericardium, superficial epicardial involvement may cause a current of injury to flow from the surface towards the underlying healthy muscle: in other words, the surface of the heart develops a negative potential. The

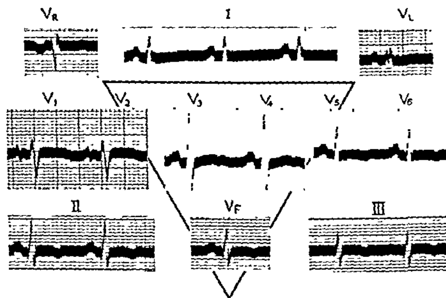


Fig 3 26—Chronic constrictive pericarditis, showing low voltage and flat T waves

situation, therefore, resembles that in myocardial infarction, but the lesion is general instead of local. Thus, in the initial stages, elevation of the RS-T segment may be seen in all chest leads, in both VL and VF, and therefore in all standard leads (fig. 3 25a). Unlike most records of acute myocardial infarction, the RS-T segment remains concave. As the underlying muscle is healthy there are no pathological Q waves. After a few days the RS-T segment regains the iso-potential level and the T wave becomes inverted (fig 3 25b). Upward coving of the RS-T segment does not occur. If pericarditis is localised the changes described may be confined to corresponding leads, but few important forms of pericarditis remain localised for long. Serial records nearly always reveal what may be called the T_2 pattern in contrast to the T_1 or T_3 types of myocardial infarction. Low voltage QRS complexes usually indicate pericardial effusion.

The electrocardiogram returns to normal as the pericarditis recovers. In chronic constrictive pericarditis, flattened or inverted T waves in all leads are permanent, and are usually associated with low-voltage QRS complexes

Fig 3 27 (a)—The effect of digitalis on the electrocardiogram showing sagging of the RS-T segment and shortening of Q-Tc to 0 33 second

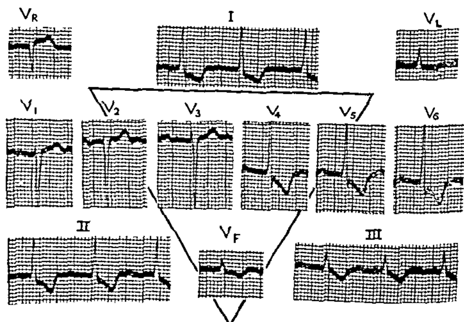


Fig 3 27 (b)—Showing gross depression of the RS-T segment or an inverted T wave with a straight proximal limb; Q-Tc is shortened to 0 36 second

(fig. 3 26) Not infrequently the P waves are widened and relatively prominent.

Digitalis T wave pattern. Digitalis depresses the RS-T segment, and shortens the Q-T interval. At first, the RS-T junction is depressed and there is downward coving of the RS-T segment, T remaining upright (fig 3.27a). In the second stage sagging is more marked and the peak of T can no longer be discerned. In extreme digitalisation the RS-T segment becomes a straight line, sloping downwards from its depressed origin to a blunt peak (fig. 3.27b).

In normal hearts these effects are seen in all leads, but especially in lead V5 and standard lead V2. When the heart is electrically horizontal they are seen best in V5, VL, and in standard lead 1; when it is electrically vertical they are best seen in V5, VF, and in standard lead 3. When the left ventricle is enlarged and the heart is horizontal the changes occur more markedly in V5, VL and standard lead 1, and the RS-T segment may be elevated and upwardly convex in V1, VF and standard lead 3 When the right ventricle is enlarged they may be most conspicuous in V1, VF and standard lead 3, and the RS-T segment may be elevated and upwardly convex in V5, VL and standard lead 1.

Anoxic T waves. Electrocardiograms taken from patients during an attack of angina pectoris may show transient depression of the RS-T

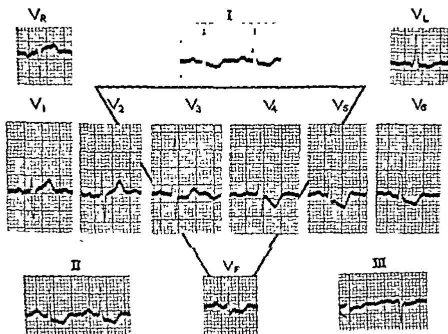


Fig 3 28 (a)—Depression of the RS-T segment during an attack of angina pectoris

Fig 3 27 (a)—The effect of digitalis on the electrocardiogram showing sagging of the RS-T segment and shortening of Q-Tc to 0 33 second

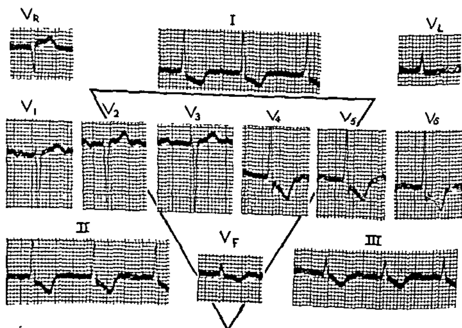


Fig 3 27 (b)—Showing gross depression of the RS-T segment or an inverted T wave with a straight proximal limb, Q-Tc is shortened to 0.36 second.

Fig 3 30—Relatively permanent depression of the RS-T segment in left ventricular surface leads in a case of angina pectoris due to occlusive disease of the coronary arteries

Myxœdema pattern. Flat or inverted T waves in all leads are characteristic of myxœdema (fig 3.31) In such cases the voltage of QRS is usually below 6 millimetres in the most favourable standard lead, and there is often bradycardia. Similar appearances may be found in chronic constrictive pericarditis, in long-standing cases of severe anæmia, particularly pernicious, and in anoxic chronic pulmonary heart disease; but in these there is commonly tachycardia In severe cases of ischæmic heart disease with

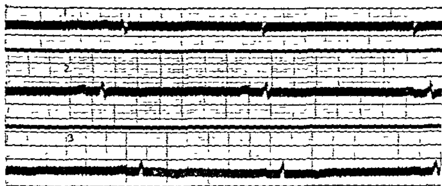


Fig 3 31—Myxœdema

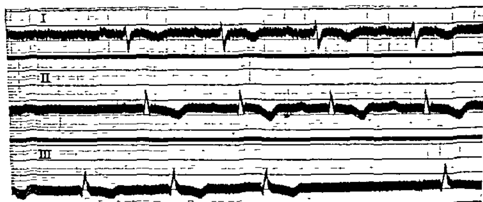


Fig 3 32—Pneumonic carditis There is partial heart block with dropped beats and inversion of the T wave in all leads

repeated myocardial infarction somewhat similar graphs may be encountered Indeed, when the whole heart is involved in any disease, and when recurrent heart failure has occurred, the voltage of QRS may be low, and the T waves flat or slightly inverted in all leads, whatever the etiology.

Carditis pattern In any form of carditis, but especially in diphtheria and least frequently in acute rheumatism, simple inversion of the T waves may occur, and may favour any lead (fig 3 32) The RS-T segment may be normal or depressed The voltage of QRS is usually normal.

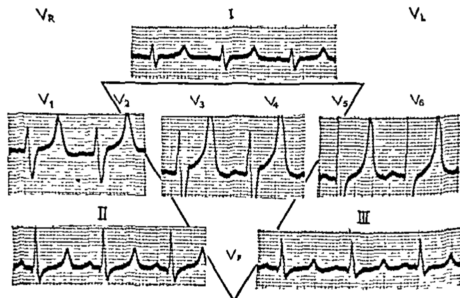


Fig 3 33—High voltage sharply peaked T waves in uræmia associated with a high blood potassium The long Q-T interval is due to hypocalcæmia. Widening of QRS, due to potassium, is well seen in the chest leads

Potassium T waves. In uræmia, when the blood potassium is high, unusually sharp T waves of high voltage are often seen (fig. 3 33). Similar T waves may be produced in normal subjects by raising the blood potassium to about 25 mg. per cent. by giving 10 to 20 G of potassium acetate by

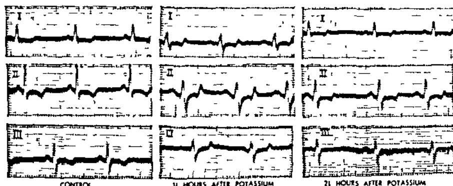


Fig 3 34—Effect of potassium on the T waves in a case of concordant left ventricular preponderance. The QRS complex is also widened

mouth.* A high blood potassium also tends to rectify many forms of inverted [illegible] which may [illegible] QRS is also

When the blood potassium is unduly low ($<$12 mg per cent.) the S-T segment and T wave may be depressed, and the P-R interval and Q-T_C prolonged (Perelson and Cosby, 1949).

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CHAPTER IV

DISORDERS OF CARDIAC RHYTHM

THE speed and regularity of the heart beat are controlled by the sino-auricular node of Keith and Flack (1907) situated in the upper part of the sulcus terminalis, anterior to, and to the right of, the mouth of the superior vena cava (fig 4 01). Approximately 70 times per minute this node discharges itself and initiates an excitation wave which spreads in all directions over both auricles Close to the opening of the coronary sinus, above the base of the tricuspid valve, on the right side of the atrial

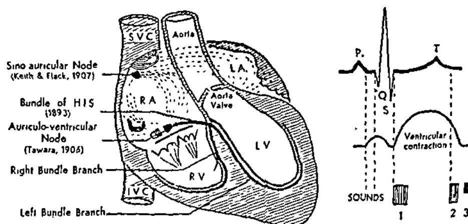


Fig 4 01—Anatomy of the conducting system.

septum is situated the auriculo-ventricular node of Tawara (1906) This also forms impulses, but at a slower rate, so that normally it is prematurely discharged by the excitation wave initiated by the S-A node. The impulse then spreads down the Bundle of His which passes horizontally to the left, to penetrate the membraneous interventricular septum, where it divides into left and right bundle branches These pass down each side of the muscular septum just beneath the endocardium. The bundle branches then break up into a network of Purkinje fibres which carry the excitatory process to the sub-endocardial myocardium.

Physiology of conduction From the "pace-maker" in the sino-auricular node the excitation wave spreads through auricular muscle at a speed of about 1,000 mm. per second. Passage through the A-V nodal tissue is believed to be relatively slow, and is estimated at 200 mm. per second. Spread down the bundle branches and the Purkinje fibres is rapid and is

probably as fast as 400 mm. per second. Conduction through the ventricles, which is believed to proceed directly outwards, is put at 400 mm per second (Lewis, 1925)

Both the S-A and A-V nodes are under direct autonomic control, being stimulated by sympathetic activity and depressed by vagal activity Cardiac accelerator nerves arise from the lateral horns of the upper 4th or 5th dorsal segments of the spinal cord, enter the sympathetic chain and pass cranially to the cervical ganglia Post-ganglionic fibres form the superior, middle and inferior cardiac nerves which terminate in the S-A and A-V nodes

IRREGULARITIES AND ALTERATION OF HEART-RATE INITIATED OR GOVERNED BY THE SINO-AURICULAR NODE

SINUS ARRHYTHMIA

There is probably no such thing as an absolutely regular heart Slight irregularity, the heart quickening with inspiration and slowing with expiration, is normal, and depends upon variations in vagal tone governed by a reflex which is thought to be initiated by receptors in the lungs Another

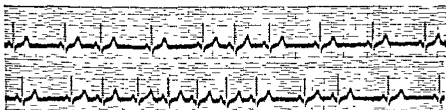


Fig 4.02—Sinus arrhythmia

form of sinus arrhythmia occurs independently of respiration Both are more common in the young and when the heart rate is slow, tend to be exaggerated by drugs which increase vagal tone (such as digitalis), and may be abolished by exercise or by atropine

Other varieties of sinus arrhythmia are not essentially different, but owe their recognition to some particular associated feature thus there is a form associated with sino-auricular block, another with sinus bradycardia and paroxysmal auricular fibrillation or flutter; a third with convalescence from certain infectious fevers, especially influenza; and so on. Increased vagal tone is common to all these types

Diagnosis is usually easy, or doubt is soon resolved by means of exercise, atropine, or amyl nitrite An electrocardiogram provides conclusive evidence (fig 4.02)

Although sinus arrhythmia is normal, it should not be regarded as a positive sign of a normal cardiovascular system, for it may occur in any form of heart disease.

SINUS TACHYCARDIA

The heart rate varies markedly in different mammals. In the elephant, for example, it is about 30 beats per minute; in the rat it is close on 600. It is considerably slower in the hare than in the rabbit. On the whole, the speed is inversely proportional both to the size and to the athletic endurance of the animal. In man the average heart rate is 72 beats per minute; but there are wide limits of normality ranging between 40 and 100. The pulse is faster in children, averaging 120 to 130 at birth, and slowing gradually during childhood to reach about 80 at puberty. The more athletic the individual the slower the pulse as a rule, and in well-trained athletes resting figures of 45 to 50 are common It follows that tachycardia may mean a heart rate faster than average, faster than the upper limit of normality, or faster than what is known to be normal for a particular individual

Applied physiology. Tachycardia has always played an impressive part as a physical sign in general medicine. It has received weighty consideration in fevers, in all forms of heart disease, in shock and hæmorrhage, in various chronic diseases such as pulmonary tuberculosis, and indeed in almost every condition; yet it can mean little unless its immediate cause is understood. This is not to decry tachycardia as a valuable sign, but to emphasise that its significance depends upon its mechanism.

The speed of the sino-auricular pace-maker is strongly influenced by the autonomic nervous system. Complete "paralysis" of the vagus may be produced within a minute by giving 2 to 3 mg of atropine sulphate intravenously, whereupon the heart accelerates to a speed of 130 to 160 per minute The cardiac output per minute rises simultaneously; but a fall in venous filling-pressure which accompanies the tachycardia may counteract this effect (McMichael and Sharpey-Schafer, 1944). The ventricular stroke-volume is diminished, even in those with higher outputs. Emotional tachycardia, as in the anxiety states, and also the tachycardia of convalescence appear to be due to diminished vagal tone.

Tachycardia may be due to a rise in pressure within the great veins and right auricle, venous receptors initiating the Bainbridge reflex by which vagal tone is reduced Under these circumstances the stroke-volume may be maintained or increased, the cardiac output per minute rising in proportion to the tachycardia or even higher This mechanism operates during effort, and in anæmia, beri-beri, arteriovenous shunt, anoxic pulmonary heart disease, generalised active Paget's disease, and pregnancy. The Bainbridge reflex is also responsible for the tachycardia so frequently seen in congestive failure.

The speed of the heart is also controlled by reflexes initiated by receptors in the aorta and carotid sinuses. When the blood pressu[illegible]ses, vagal tone is increased, and the heart slows; when it falls, vagal to[illegible]iminished, and the heart quickens (Marey's Law) This is the mechanis[illegible] brady-cardia associated with conditions causing a transient rise of bl[illegible]ure,

such as acute nephritis, and it is part of the mechanism controlling the tachycardia of low blood-pressure states

Anoxia may cause tachycardia by direct action on the central nuclei, or possibly reflexly through the carotid sinus. Just what part it plays in the production of tachycardia in anæmia and cor pulmonale is uncertain Thyroxin and fever have a direct stimulating action on the pace-maker, and so has adrenaline; but the latter may also excite the carotid sinus slowing reflex by raising the blood pressure, so that the heart rate may change but little. The elevated cardiac output which accompanies the tachycardia is also probably due in part to a direct action on the heart In the case of adrenaline the cardiac output may rise when there is no change in heart rate or blood pressure (McMichael and Sharpey-Schafer, 1944)

Differential diagnosis. From the clinical point of view, sinus tachycardia must be distinguished from auricular flutter and from paroxysmal tachycardia. This is usually possible at the bedside Sinus tachycardia varies in

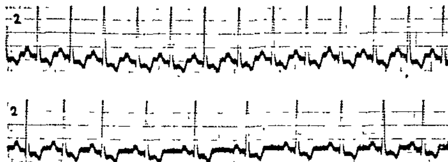


Fig 4 03—Sinus tachycardia slowed by carotid sinus compression

rate from minute to minute, or at least from hour to hour, and it varies with emotion, effort, and change of posture Carotid sinus or eyeball compression and release result in gradual rather than abrupt slowing and quickening of the pulse respectively, although changes may be difficult to detect with fast rates In auricular flutter (and sometimes in paroxysmal auricular tachycardia) the rate is usually fixed, neither varying spontaneously nor with emotion, effort, or change of posture; whilst on carotid sinus pressure slowing is abrupt, often to half the rate, 2 . 1 physiological auriculo-ventricular block being converted into a 4 1 relationship, and on release, reversion to the original rhythm is again abrupt, and may not take place for several seconds Even without so precise a clinical analysis, the degree of slowing may yet be too gross for sinus tachycardia In paroxysmal nodal and ventricular tachycardia the rate is also fixed, and carotid sinus pressure either stops the attack abruptly, as in 50 per cent of the nodal cases, or has no effect whatever If it is impossible to interpret the results of carotid sinus pressure clinically, the problem may be solved by combining the manœuvre with an electrocardiogram (fig. 4 03) It should be

explained that an electrocardiogram *per se* may not afford certain distinction between these three rhythms, although lead V_1 or CR1 greatly facilitates analysis.

Effect on the heart. Sinus tachycardia presents an important problem in relation to heart failure. Is it a causal factor or merely a reflection of cardiac embarrassment? Or is it part of a compensatory adjustment, beneficial under the circumstances? Such questions are difficult to answer directly; but the presentation of some of the relevant facts may help to clarify the issue. A normal heart tolerates any natural degree and duration of sinus tachycardia, rates approaching 200, for example, being common during violent exertion, and persistent rates of 120 or so being endured for over 20 years in certain cases of Da Costa's syndrome without harmful results. On the other hand, diseased hearts frequently develop congestive failure with heart rates of 150 to 200 in auricular flutter or paroxysmal tachycardia, the effect being attributed to overwork and to fatigue resulting from insufficient diastolic rest. The tachycardia of the hyperkinetic forms of *cardiovascular disorder (thyrotoxicosis, anæmia, anoxic pulmonary heart* disease, beri-beri, arterio-venous aneurysm, and generalised Paget's disease) is part of the physiological mechanism maintaining a high cardiac output, and therefore performs a useful function; but when the heart fails, i.e. when it is overloaded, the cardiac output falls and the tachycardia is wasted. Under such circumstances tachycardia reflects cardiac embarrassment, and deprives the heart of diastolic rest. In the hypokinetic forms of heart failure, such as those which may be seen in cases of hypertension and mitral stenosis, tachycardia due to the operation of the Bainbridge reflex is a reflection of cardiac distress from the start, and serves no useful purpose. In chronic constrictive pericarditis, and to a lesser extent in high-pressure pericardial effusion, tachycardia may provide the only means of maintaining an adequate cardiac output, for the stroke-volume is strictly limited. In the active forms of carditis (rheumatic, diphtheritic, and Fiedler's), and in bacterial endocarditis, the heart rate may be disturbed by local pathology, fever, toxæmia, or (in diphtheria) by circulatory collapse, and probably adversely affects the heart On the whole it may be said that the heart tolerates sinus tachycardia, which tends to deprive it of rest, better than a high cardiac output, and much better than a raised blood pressure, both of which increase its work.

There is no treatment for sinus tachycardia itself; but attention should be paid to its cause

SINUS BRADYCARDIA

As already stated, heart rates of 45 to 50 per minute are common in athletes. Some individuals, irrespective of their physical training, have a naturally slow pulse. Sinus bradycardia is a feature of certain diseases, notably myxœdema, obstructive jaundice, and aortic stenosis; and it is not uncommon during convalescence from certain fevers, especially influenza.

It also occurs when the blood pressure is raised rather suddenly, as in acute nephritis, the slowing being reflex, through the sino-aortic afferents and the vagus. It is a familiar sign of lesions that increase the intracranial pressure, when it may be due to direct stimulation of central nuclei Slowing of the pulse may be induced temporarily by carotid sinus or eyeball pressure; as a transient event it occurs naturally in vaso-vagal syncope.

The differential diagnosis between sinus bradycardia, sino-auricular block, and heart block, can usually be made at the bedside; but electrocardiographic confirmation is advised. In sinus bradycardia the pulse quickens gradually with effort, atropine, or amyl nitrite, in sino-auricular block and sometimes in 2 : 1 heart block, the rate doubles abruptly, whilst in complete heart block the degree of acceleration is barely perceptible. Heart block may also be recognised by studying jugular pulsation (see page 120).

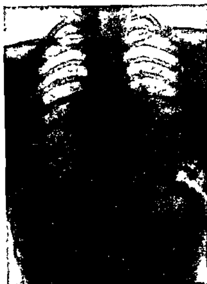


Fig 4 04—Relative cardiac enlargement due to sinus bradycardia

One of the consequences of sinus bradycardia is an increased ventricular stroke-volume of sufficient degree to maintain a normal cardiac output per minute. When the heart rate is 40, the stroke-volume approaches double the average normal, the diastolic heart size is larger than usual (fig. 4 04), and in time hypertrophy may occur Such enlargement is physiological

When the speed of the pace-maker approaches 40 per minute, it may become slower than the natural speed of impulse-formation in the auriculo-ventricular node, in which event nodal rhythm occurs As sinus arrhythmia is often associated with bradycardia it is more usual to see irregular examples of ventricular escape, the A-V node taking over whenever a pause is unusually long (fig. 4 05) Nodal rhythm would supervene more frequently if the influences which retarded the sinus node did not also depress the A-V node

Sinus bradycardia is often associated with sinus arrhythmia, sometimes with auricular ectopic beats, and rarely with paroxysmal auricular fibrillation or flutter in elderly subjects Vagal influences appear to be responsible.

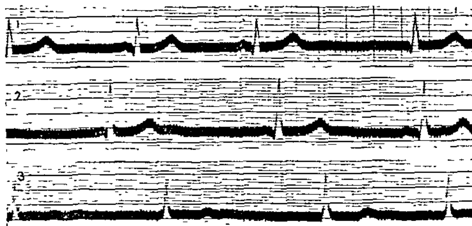


Fig 4 05—Nodal escape in sinus bradycardia

SINO-AURICULAR BLOCK

There are three types of sino-auricular block, corresponding to similar varieties of A-V block First, beats may be dropped irregularly, the pauses being roughly equal to two normal intervals (fig. 4 06), like the dropped beats of partial A-V block with fixed prolonged P-R interval Second, beats may be dropped more or less regularly, the pauses being always less than two normal intervals, like partial A-V block with progressive lengthening of the P-R interval until conduction fails – the Wenckebach type. Third, there may be 2 1 sino-auricular block, every second beat being dropped; this gives rise to a slow regular heart rate which doubles on effort or with atropine (fig 4 07) To understand these phenomena it is necessary to appreciate the fact that there is no electrocardiographic representation of the formation and discharge of the excitatory impulse at the sinus node, the first wave (P) of the electrocardiogram recording the passage of the impulse through the auricles, so that failure of conduction between the S-A node and the auricles can only be inferred

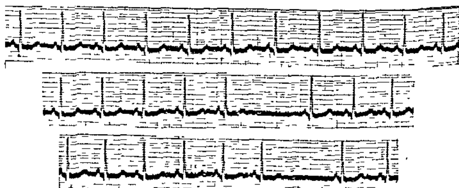


Fig 4 06—Sino-auricular block, showing irregular dropped beats

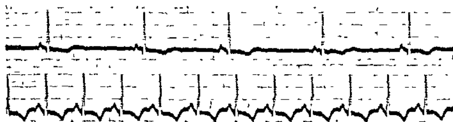


Fig 4 07—Sino-auricular block the rate doubles on effort

Sino-auricular block is usually encountered in normal individuals, the first two types being commonly associated with sinus bradycardia It is a manifestation of increased vagal tone, and may be abolished with atropine When there is 2 : 1 block, and a pulse rate of about 40 per minute, fluoroscopy may reveal cardiac enlargement due to the large stroke-volume necessary to maintain a normal cardiac output As with sinus bradycardia,

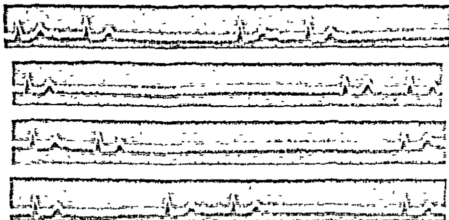


Fig 4 08—Cardiac standstill occurring spontaneously in sino-auricular block
(*By courtesy of Dr Raymond Daley*)

ventricular escape may occur, and would probably be more common if the A-V node were not also depressed.

There are no symptoms of sino-auricular block *per se*; but occasionally short periods of cardiac standstill, with dizziness or syncope, may occur, and appear to be due to bursts of extreme vagal activity (fig 4 08) They may be prevented by atropine Attacks of this kind may be readily induced in susceptible individuals by carotid sinus pressure (fig 4 09)

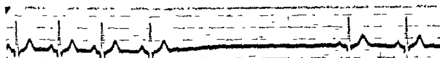
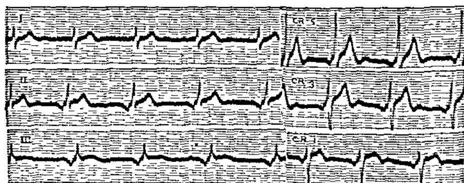


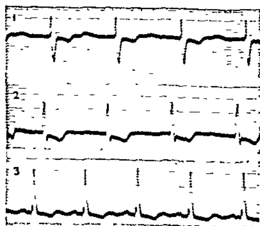
Fig 4 09—Cardiac standstill due to carotid sinus compression



(a) An inverted P wave occurs after QRS.



(b) Anverted An inverted P wave precedes QRS ("Coronary sinus rhythm")



(c)—The P wave is invisible, being buried in QRS (leads 1 and 2, lead 3 shows normal rhythm)

Fig. 4 10—Nodal rhythm.

NODAL RHYTHM

The sinus node is the pace-maker of the heart only because its inherent rate of impulse-formation and discharge is quicker than that of any other focus endowed with a similar capacity; but if it is sufficiently depressed, as by cooling, some other focus may form its impulses at a faster rate, and so become the temporary pace-maker, and in fact this function usually falls upon the auriculo-ventricular node. Under such circumstances auricular excitation is retrograde, and the electrocardiogram usually shows an inverted (or deformed) P wave just after the QRS complex, and a heart rate of 40 to 60 per minute (fig 4.10a) Sometimes, however, the P wave may precede (fig. 4.10b) or coincide with the QRS complex, or it may be absent altogether owing to retrograde block (fig. 4.10c) Occasionally, it may shift

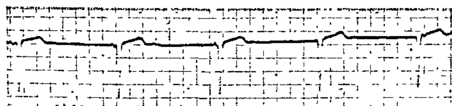


Fig 4 11—Shifting nodal rhythm

its position from moment to moment (shifting or sliding nodal rhythm; fig 4.11), but if such graphs are examined critically, some are seen to be examples of sinus bradycardia with frequent ventricular escape (so-called wandering or shifting pace-maker), and others reveal progressive lengthening of the period of retrograde conduction to the auricles until an auricular beat is dropped, after which the P wave reverts to its initial position, the cycle being repeated indefinitely (partial retrograde block).

Nodal rhythm may be discovered by chance in healthy individuals; it may occur in active rheumatic, diphtheritic, and Fiedler's carditis; it may be momentarily induced by carotid sinus pressure; and it may follow thrombosis of the right coronary artery above the origin of the branch to the sinus node (this branch arises from the left coronary artery in 40 per cent. of cases). but its only common cause is digitalis therapy

Nodal rhythm is under autonomic control, the heart rate being slowed by vagal stimulation and accelerated by atropine and exercise (White, 1915) It is a harmless rhythm change, gives rise to no symptoms, and requires no treatment. When due to digitalis, there is no need to stop the drug

HEART BLOCK

When any organic lesion or functional disturbance impedes conduction through the bundle of His, or through both its main branches, we may speak of heart block There are four grades prolonged P-R interval,

dropped beats, partial block with fixed auriculo-ventricular relationship, and complete heart block

PROLONGED P-R INTERVAL

As discussed on page 78 the upper limit of the normal P-R interval should not exceed 0 22 second In partial heart block it frequently measures 0 28 to 0 32 second In extreme cases, or when there is associated tachycardia, electrocardiograms may show P coinciding with, or even preceding, the previous T wave (fig 4.12)

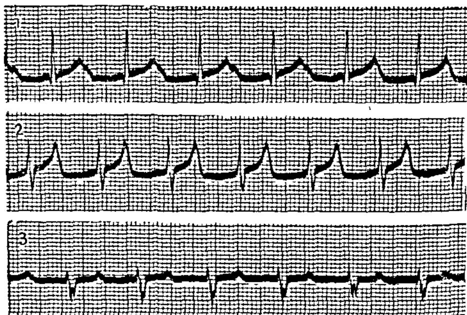


Fig 4 12—Prolonged P-R interval, with P coinciding with the previous T wave

Prolongation of the P-R interval may be transient or permanent, or it may develop into a higher grade of block As a transient phenomenon (when it may be abolished by the intravenous injection of 2 to 3 mg. of atropine sulphate), it is especially characteristic of any form of active carditis, but it may also be due to digitalis, to coronary thrombosis, or to temporary nutritional changes from other causes, and it may be induced by carotid sinus pressure. Permanent delay in conduction may result from an inflammatory scar involving the bundle of His, as in old rheumatic heart disease, or from ischæmic fibrosis.

Although partial heart block of this kind is essentially an electrocardiographic diagnosis, it may be suspected clinically on occasions by noting delay between the auricular and ventricular components of cervical venous pulsation, by observing a gap between a presystolic murmur and the first heart sound in cases with mitral stenosis, or by detecting Cannon waves

in the neck (p. 122). Its practical importance lies in its value as a sign of active rheumatic carditis.

No special treatment is required

PARTIAL HEART BLOCK WITH DROPPED BEATS

In a slightly higher grade of partial heart block, conduction through the bundle of His fails altogether from time to time so that ventricular beats are dropped. In the type first recognised by Wenckebach (1899) the P-R

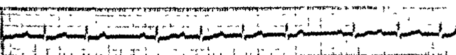


Fig 4 13—Partial heart block with dropped beats (Wenckebach type)

interval shortens considerably after a beat is dropped, but subsequently lengthens progressively from cycle to cycle until conduction again fails (fig 4.13) In another type (Hay, 1906) the P-R interval is fixed and beats are dropped irregularly and unpredictably

The condition may be suspected clinically, but cannot be so distinguished from partial sino-auricular block, nor from pauses following extremely premature and therefore inaudible ectopic beats It is commonly transient and recovers spontaneously, but occasionally progresses to complete heart block

PARTIAL HEART BLOCK WITH FIXED A-V RELATIONSHIP

Relatively stable forms of partial heart block may be encountered, usually with a 2 : 1 auriculo-ventricular relationship (fig 4 14), but occasionally

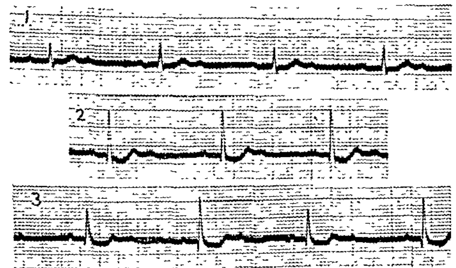


Fig 4 14—2-1 heart block

with 3 : 1 or even 4 : 1 A-V ratios. These usually progress to complete heart block; they are much less common in active carditis than in ischæmic cases

Clinically, 2 . 1 heart block has to be distinguished from sino-auricular block, from sinus bradycardia with a heart rate of about 40 per minute, from nodal rhythm, and from complete A-V dissociation. Failure to quicken appreciably with effort or atropine excludes sino-auricular block and sinus bradycardia (and usually nodal rhythm). If isolated auricular waves can be detected in the veins of the neck, their regular timing may distinguish 2:1 block from complete A-V dissociation.

COMPLETE HEART BLOCK

Etiology. Complete auriculo-ventricular dissociation is very rare in active rheumatic carditis, but less so in diphtheritic carditis; it may be induced by digitalis, especially in cases of auricular fibrillation, and has been caused by hæmorrhage into the bundle of His from trauma or asphyxia, and by primary or secondary neoplasm About 10 per cent. of cases are congenital and may be associated with ventricular septal defect. As a rule, however, complete heart block is associated with ischæmic or hypertensive heart disease, with syphilitic aortitis, or with extensive calcification of the aortic cusps or mitral ring in elderly atherosclerotic subjects, and is due to a fibrotic or calcified lesion in the bundle of His, or in both its main branches.

Clinical features A-V dissociation is four times more common in males than in females, and 84 per cent. of cases occur in patients over 50 years of age (Campbell, 1944) It is usually permanent, but under special circumstances may be transient or even paroxysmal (Lawrence and Forbes, 1944) It is characterised by an extremely slow heart rate, by a water-hammer or collapsing pulse, by elevation of the venous pressure, by cervical venous pulsation unrelated to ventricular contraction, by audible independent auricular sounds, by the occurrence of Cannon waves in the neck and varying intensity of the first heart sound, by general enlargement of the heart, and by syncopal attacks of a special kind It is proved electrocardiographically (figs. 4 15a and b).

Whilst the pulse rate is usually about 28 to 36 per minute, based on the inherent rate of impulse-formation of the idio-ventricular pace-maker distal to the block in the bundle of His, it may be so slow as to induce a state of continual faintness (fig 4.15b), as in the case originally described by Spens (1793) in which it fell to 9 beats per minute At the other extreme, complete A-V dissociation may be seen with a ventricular rate of over 100, the ventricles sometimes beating more rapidly than the auricles (fig 4 16) On the whole, rates are faster when QRS is normal in width, slower when the QRS resembles left or right bundle branch block (Kay, 1948) Idio-ventricular pace-makers are little affected by stimuli which influence the S-A and A-V nodes, so that the pulse rate usually remains remarkably

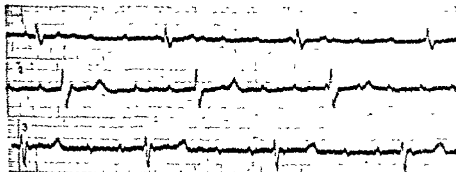


Fig. 4 15 (a)—Complete heart block Ventricular rate 18 beats per minute

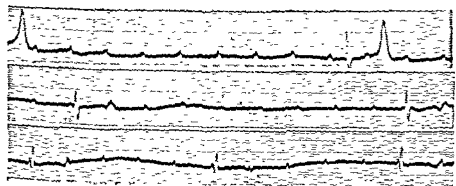


Fig 4 15 (b)—Complete heart block Ventricular rate 10 beats per minute

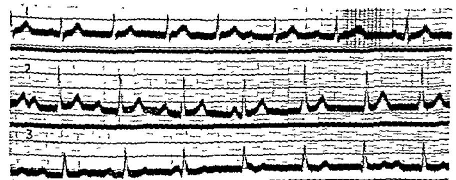


Fig 4 16—Complete A-V dissociation with the ventricles beating faster than the auricles

constant in complete heart block In transient or paroxysmal cases, however, in which a functional element may be present, temporary restoration of sinus rhythm may accompany fever, as in the case described by Gerbezius in 1719 (Major, 1932).

A high systolic blood pressure is usual, and is due to the large ventricular stroke-volume Owing to associated vasodilatation, however, the pressure is not well maintained, but tends to fall away rapidly in diastole, giving rise to a collapsing pulse and to a rather low diastolic blood pressure.

Under favourable circumstances inspection of cervical venous pulsation may reveal auricular waves ("a" waves) independent of ventricular events ("c" and "v" waves), as noted by Stokes (1846). Simultaneously may be heard the faint sounds of isolated auricular contractions (the semi-beats of Stokes), either at the apex beat or down the left border of the sternum

Venous cannon waves occur when the P wave falls between QRS and T, i e. when the auricle contracts against a closed tricuspid valve, and are easily recognized by their abrupt quality, high amplitude and variability Changing intensity of the first heart sound is equally characteristic: the loudest sounds are heard when the P-R interval is around 0 10 to 0.12 second, auricular contraction then forcing the mitral cusps wide open just before ventricular systole (Levine, 1948)

Cardiac enlargement is usually more conspicuous than that seen in sino-auricular block or in sinus bradycardia, but is of the same quality, unless the size and shape of the heart are altered by other effects of the underlying disease process

The cardiac output can only be maintained by a large stroke-volume propelled with great force Diastolic distension is favoured by a compensatory rise in venous pressure, and this must be very considerable during effort The early development of congestive failure is readily understood

Stokes-Adams attacks Syncope due to ventricular asystole (Stokes-Adams attacks) occurs in about 50 per cent. of cases, and is especially common when partial block becomes complete Loss of consciousness is abrupt, without warning If standing, the patient collapses, and lies limp, still, pale and pulseless, with fixed, dilated pupils – as if dead, breathing, however, continues If the attack lasts long enough, i.e for more than 10 seconds or so, twitchings commence, and may progress to convulsions; and if ventricular asystole continues for more than 2 or 3 minutes, recovery is rare. As a rule, however, ventricular beating is resumed after a few seconds, consciousness returns abruptly, and a vivid flush ensues. When an attack occurs in bed, the lack of warning, short duration of unconsciousness, and abrupt return of full possession of the faculties, may prevent a dull patient from being aware of the fit, and he may only notice the flush. The sequence of events, both symptomatically and objectively, is so characteristic as to make the diagnosis probable on the history alone – a point of some importance in patients with paroxysmal block who may present themselves with

normal sinus rhythm In such cases carotid sinus pressure may provoke an attack or induce paroxysmal heart block (fig. 4 17).

Physiologically, Stokes-Adams attacks are due to depression of a potential or established idio-ventricular pace-maker in cases of complete heart block; the ventricles stand still while the auricles continue to beat They are apt to occur when partial block becomes complete, either because such an event is usually associated with some depressive influence on conduction which may also depress ventricular pace-makers (even though considered beyond vagal control), or because idio-ventricular pace-makers are by nature initially sluggish. When complete block is well established, attacks

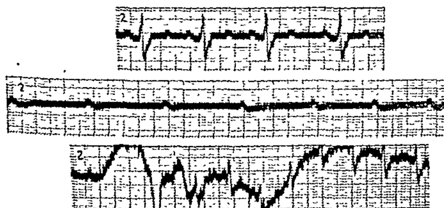


Fig. 4 17—Stokes-Adams fit artificially provoked in a patient with paroxysmal complete heart block

may still occur, but are less common. The abrupt loss of consciousness depends upon sudden total failure of cardiac output Twitching is due to cerebral anoxia, and is not seen in short attacks Convulsions are of two types, one being an exaggeration of anoxic twitching, the other occurring after restoration of ventricular action and synchronising with the flush (Formijne, 1938). In the second type, convulsions and flushing appear to be due to carbon dioxide depletion in the blood stagnant in the lungs during the phase of asystole with continued respiration, and to vasodilatation resulting from accumulation of tissue metabolites, so that when ventricular beating is resumed, blood rich in oxygen but containing practically no carbon dioxide, is thrown abruptly into a widely dilated vascular bed. More often a period of apnœa follows the attack, with or without subsequent Cheyne-Stokes breathing (Griffith, 1921). Apnœa, of course, may also occur towards the end of long periods of ventricular asystole, when it is due to failure of the respiratory centre resulting from profound cerebral anoxia

An important complication of Stokes-Adams attacks is paroxysmal ventricular tachycardia or fibrillation (Parkinson, Papp and Evans, 1941). In such cases it may be impossible to determine clinically whether uncon-

sciousness is due to asystole or to ventricular fibrillation. It is probable that many deaths are due to the supervention of such rhythm changes rather than to asystole

Prognosis. Congenital and transient cases do relatively well, unless the disease responsible is serious for other reasons. The outlook in paroxysmal and acquired permanent cases, however, is poor, life expectancy averaging 4½ years (Graybiel and White, 1936; Campbell, 1944). Those with a history of Stokes-Adams fits have a much worse prognosis than those without, the majority of them dying suddenly. Those without fits usually die from congestive heart failure.

Treatment The most effective prophylactic treatment for faintness or syncope is the oral administration of ephedrine, ½ grain (32 mg.) t d s. If attacks are frequent and the patient bedridden, adrenalin, 0.5 mg. (8 minims or 0.5 ml of a 1 . 1,000 solution) should be injected subcutaneously, and repeated every two to six hours. Sublingual nor-adrenalin is also helpful. Both ephedrine and adrenalin prevent undue depression of the ventricular pace-maker, and encourage the heart to beat a trifle faster. It is sometimes said that idio-ventricular rhythm cannot be influenced by any of the drugs or manœuvres that are known to effect the sinus node This is not always strictly true, but changes are admittedly slight Effort, for example, may quicken the ventricular rate in complete heart block; the adrenergic drugs, fever, and even atropine may also do so In treatment, however, atropine is valueless alone, although it may enhance the effect of adrenaline. Barium chloride had a vogue, its action depending upon its power to excite ventricular ectopic beats and so to prevent ventricular standstill; but this is a poor substitute for the physiological benefit provided by ephedrine. In paroxysmal cases, when some functional disturbance must be postulated, inhalations of amyl nitrite may abort attacks (Lawrence and Forbes, 1944).

A problem arises when repeated seizures are partly due to paroxysmal ventricular tachycardia or fibrillation, for if it is uncertain whether unconsciousness is due to asystole or to fibrillation, the administration of adrenaline becomes hazardous, as the drug encourages the latter rhythm-change. For this reason electrocardiographic analysis is advised whenever possible.

Treatment of the primary cardiac condition may help. This applies especially to the rare transient cases associated with active carditis or myocardial infarction, and to permanent cases associated with syphilitic aortitis Very rarely a small gumma may interrupt the conducting pathway, and the resulting block may be cured with iodides (Major, 1923).

If congestive heart failure calls for digitalis therapy, the drug should not be withheld on account of coincident heart block, but should be administered with caution Massive and intravenous doses should be avoided, but digitalis leaf, 3 grains (0 2 G) t d s. on the first day, 2 grains (0.13 G.) t.d s. on the second, and 1 grain (65 mg.) t d s. thereafter, until an adequate effect is obtained or until signs of intoxication occur, is usually safe. Should a Stokes-Adams fit appear to be provoked, the drug must be discontinued.

BUNDLE BRANCH BLOCK

Although bundle branch block is not strictly a disorder of rhythm, it may be discussed here conveniently on account of its close pathological relationship to other forms of conduction defect.

Anatomy. Bundle branch block occurs when some organic lesion interferes with conduction through one or other of the two main branches of the bundle of His. As may be seen from figure 4 01, the main bundle, after piercing the membranous septum, divides into two, one branch passing down each side of the muscular interventricular septum just beneath the endocardium, and spreading out fan-wise distally; the left branch may subdivide into anterior and posterior divisions in the lower half of the septum (Mahaim, 1931). The A-V node, bundle of His, and posterior division of the left bundle branch receive their blood supply from perforating septal

supplied by perforating septal branches of the left anterior descending coronary artery (Gross, 1921). Considerable variations occur, however, especially as vital reactions to ischæmia

Nomenclature. When the left bundle branch is interrupted, the excitatory process reaches the right ventricle first, through the relatively normal right bundle branch, and spreads throughout that chamber before passing across to the left. The right ventricle therefore contracts first The electrocardiogram, described and illustrated fully in Chapter III, shows a wide QRS complex, measuring from 0.11 to 0.18 second, the main deflection of which is usually upright in lead 1 and downward in lead 3, with marked slurring or notching, and followed by a conspicuous T wave, usually in the opposite direction. Right bundle branch block (Wilson *et al*, 1934) is characterised by widening of the initial ventricular deflection to 0.11 to 0.14 second, by late slurring of QRS – usually best seen in S_1 – and by an upright T wave in lead 1 (page 93). That the first type of graph described represents left bundle branch block has been proved by the reconstructed vectorcardiograms (monocardiograms) of Mann (1931), by the electrocardiographic discoveries of Wilson and his colleagues (1932), by kymographic and polygraphic studies revealing delayed left ventricular events (Wolferth and Margolies, 1935), by experiments on revived human hearts in normal position in which one or other bundle branch has been cut (Kountz, 1936), and by simultaneous electrocardiographic, phonocardiographic, and polygraphic records demonstrating and analysing ventricular asynchronism (Braun-Menendez and Solari, 1939) The detailed histological work of Mahaim (1931), which at first appeared to support the original view in which the nomenclature for left and right bundle branch block was reversed, has been ably reviewed by Yater (1938), who presented extensive histopathological evidence of his own, and concluded that the bilateral lesions invariably demonstrable rendered reliable interpretation difficult,

but that ...
the ... branch block is com-
mo ... lesions involving the left side of the heart; whereas right bundle branch block is usually associated with enlargement of the right ventricle This general principle was recognised by Tung and Cheer (1933) and by Bayley (1934)

Etiology Left bundle branch block is usually due to hypertensive heart disease, ischæmic heart disease, or aortic valve disease; right bundle branch block to mitral stenosis, atrial septal defect, or massive pulmonary embolism Either form may occur in active rheumatic, diphtheritic or other



Fig 4 18—Alternating left bundle branch block

form of carditis, in any disease affecting the heart as a whole, such as thyrotoxicosis and fibrosis of the myocardium of known or unknown etiology; and as a result of any local lesion such as neoplasm Partial forms are common and tend to progress, on the other hand, both left and right bundle branch block may be transient, paroxysmal, or even alternating (*fig* 4 18), *sometimes in association with paroxysmal tachycardia, auricular flutter, or fibrillation;* sometimes during an episode such as acute myocardial infarction, congestive heart failure, or massive pulmonary embolism, but also spontaneously Right bundle branch block is sometimes found in otherwise healthy individuals, even in youth.

Clinical features Clinically, left bundle ...
by ...
bra ... sound In many cases, how..., no such clue is afforded, and its existence is only discovered electrocardiographically When the heart is enlarged and it is uncertain which chamber is mainly involved, the presence of left or right bundle

branch block points strongly to the homolateral ventricle Left bundle branch block provides convincing proof of serious heart disease, but right bundle branch block must be interpreted more cautiously Neither form is influenced by digitalis, atropine, or by any of the adrenergic or cholinergic drugs.

Prognosis. The average life expectancy for cases of bundle branch block in general has been estimated at 3 years (Campbell, 1944), but it should be clearly understood that in any given patient the prognosis is that of the underlying heart disease, and is not influenced by the conduction defect Again, if right bundle branch block is found in an otherwise normal individual, the outlook does not differ from normal controls (Wood, Jeffers and Wolferth, 1935).

ECTOPIC BEATS

Ectopic beats are premature systoles induced by the discharge of some ectopic impulse-forming focus situated anywhere in auricular, nodal, or

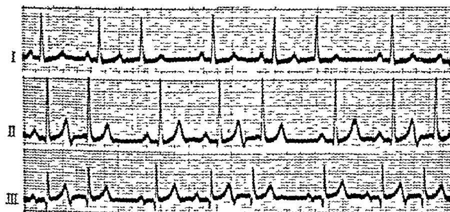


Fig 4 19—Auricular ectopic beats

ventricular tissue. They are necessarily premature because all potential impulse-forming foci are otherwise discharged by the excitation which reaches them from the sinus node

Physiology In the auricular type (fig 4 19) the P wave is abnormal in shape or direction according to the site of the ectopic focus and to the direction in which the impulse flows over the auricles. In these cases, the partially charged sinus node is discharged when the impulse reaches it, so that the compensatory pause following the ectopic beat is slight, being equal to a normal cycle plus the interval between the onset of the ectopic and the arrival of the retrograde excitatory process at the S-A node The timing of the heart beat is permanently altered The ventricular complex is usually normal, but may be slightly deformed as a result of a functional defect in

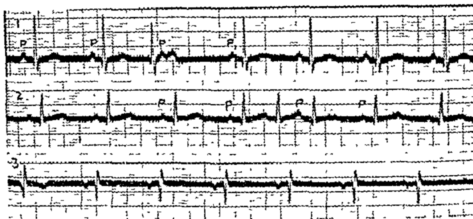


Fig 4 20—Nodal ectopic beats Slight deformity of QRS is due to fatigue block In lead 1 the P wave immediately after the ectopic is blocked In lead 2 the nodal ectopic is interpolated In both there is retrograde block

conduction If an auricular ectopic beat is very premature it may be blocked altogether

Nodal ectopic beats (fig 4 20) are premature beats arising in any part of the auriculo-ventricular junctional tissue. The QRS complex is normal or slightly deformed as described above, but the P wave is inverted, and occurs just before, during, or just after the QRS complex, according to the more *proximal or more distal site of the ectopic focus,* and to the degree of resistance opposed to retrograde conduction. Discharge of the sinus node (unless there is retrograde block) again prevents a full compensatory pause.

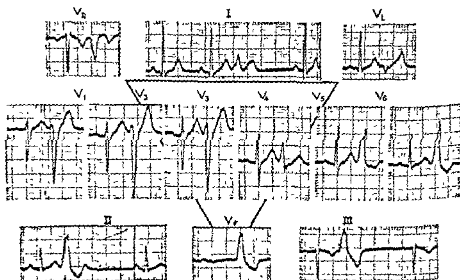


Fig 4 21—Right ventricular ectopic beats

Ventricular ectopic beats are characterised by a full compensatory pause, for the sinus node is not discharged by the premature impulse, owing to retrograde block (physiological) in the bundle of His, or to natural delay in retrograde conduction, and so continues to function at its usual time. Its first discharge after the ectopic, however, is blocked by the refractory state of the ventricles, and so there is a pause until its second discharge. The final timing of the heart beat therefore remains unchanged. Electrocardiographically, a ventricular ectopic beat resembles a bundle branch block

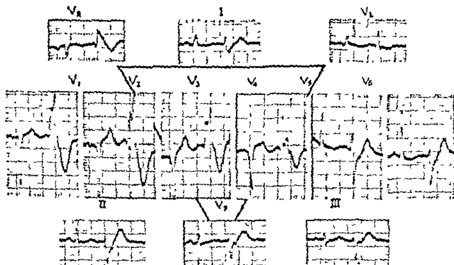


Fig. 4.22—Left ventricular ectopic beats causing coupling

complex, QRS being widened and notched, and T being prominent and usually in the opposite direction. When the deflection is like left bundle branch block, the ectopic focus lies in the right ventricle (fig. 4.21), when QRS is like right bundle branch block, the ectopic focus lies in the left ventricle (fig. 4.22). There are many variations, however, depending upon the exact site of the irritable focus (Barker *et al.*, 1930, Kountz, 1936).

Premature beats have a smaller stroke-volume than normal, and if very premature may not be perceptible at the wrist, or audible with a stethoscope. The beat which follows is fuller than usual, and is appreciated by the patient as a hard thump. This is a matter of cardiac filling: the earlier the ectopic beat, the emptier the heart, the longer the compensatory pause, the fuller the heart. The blood pressure varies directly with the amplitude of the pulse.

Clinical diagnosis. Clinically, ectopic beats must be distinguished from other irregularities, especially from auricular fibrillation and from partial heart block with dropped beats. Whilst this may be easy in the majority of cases, confusion arises with multiple auricular ectopic beats which may be indistinguishable from auricular fibrillation, and with inaudible imper-

ceptible or blocked ectopic beats which mimic partial heart block with dropped beats. Alternate ectopic beats or coupled beats may be confused with S-A block when very premature, with a dicrotic or bisferiens pulse, or even with pulsus alternans. If there is any doubt, the effect of effort, amyl nitrite, or of 1 mg of atropine sulphate should be determined: ectopic beats usually disappear as the heart quickens, and may be exaggerated as it slows down again.

Etiology. Experimentally, ectopic beats may be produced by electrical stimulation of any part of the heart. Certain drugs, notably digitalis, barium chloride, and adrenaline, may produce them Excessive use of tobacco occasionally seems responsible. They are common in pregnancy. Whilst almost any state of ill-health may be blamed for their occurrence, no common factor has been discovered, and in the majority of cases there is no evidence of structural disease of the cardiovascular or other systems. Occasionally, however, auricular ectopic beats may herald auricular fibrillation, especially in mitral stenosis and thyrotoxicosis. Under certain circumstances, also, ectopic beats are probably due to organic disease. for example, their occurrence during the course of diphtheria may be due to toxic carditis, but as innocent ectopic beats are common enough after simple streptococcal tonsillitis, and indeed during convalescence from any fever, it is impossible to draw any conclusion from their presence. Again, ectopic beats following coronary thrombosis are probably significant, and to be explained by irritable foci set up by ischæmia, but as they are equally common in conditions which may simulate myocardial infarction, e g. gall-bladder disease, diaphragmatic hernia, upper abdominal catastrophies, acute anxiety states and the like, they are of no diagnostic value. On the whole, therefore, it is wise to assume the innocence of ectopic beats under any conditions, and to judge organic disease on other grounds.

Treatment. Many patients are unaware of premature systoles; others may seek relief from palpitations. Treatment includes fresh air, exercise, and a healthy physiological life. Of drugs, potassium bromide 10 grains (0.65 G.) t d s , phenobarbitone ½ grain (32 mg) t d s., or quinidine 5 grains (0.32 G.) t d s may prove effective. Alternate ectopic beats (coupling) due to digitalis provide good grounds for stopping the drug or reducing its dose Potassium salts are efficient (Sampson and Anderson, 1932, Castleden, 1941), but the large dose usually required is not without danger of sudden death, and may provoke symptoms as unpleasant as the palpitations, chiefly nausea and vomiting. the chloride or acetate is employed as a 10 to 20 per cent aqueous solution, and may be given by mouth in doses of 2 to 6 G., three or four times a day. Larger doses are not advised, and when the maximum recommended is being administered, the patient should be confined to bed, especially if there is underlying organic heart disease. Reassurance is important, and should be unconditional and convincing, for it should be remembered that ectopic beats rarely constitute a complaint except in those prone to morbid anxiety.

EXTRASYSTOLES

The term "extrasystole" should be reserved for interpolated ectopic beats (fig. 4.23). These are true extra heart beats and occur when the impulse from the sinus node, immediately after the ectopic beat, manages to excite the ventricles. They are usually ventricular, but may be nodal (fig. 4 20)

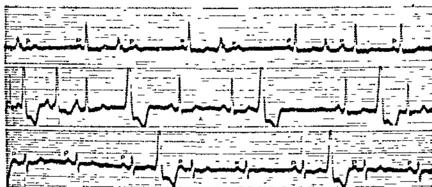


Fig 4 23—Interpolated ventricular ectopic beats

PAROXYSMAL TACHYCARDIA

When ectopic beats occur in rapid and regular succession from the same focus, one may speak of paroxysmal tachycardia. The name was introduced by Bouveret in 1889. The ectopic focus may be supraventricular (auricular or nodal), or ventricular. The electrocardiographic complexes in the three types are precisely the same as those in the three types of ectopic beat.

The patient usually complains of attacks of palpitations characterised by the abruptness of their beginning and end, by the rapidity and regularity of the beats, and by the relative well-being of the patient (Cotton, 1867). Until an attack is witnessed, the diagnosis rests upon an accurate history Experience shows that most careful cross-examination is required to establish the true sequence of events It is not enough to determine that the onset is sudden, it is necessary to be sure it is abrupt. that the full velocity of the attack is reached immediately in the space of one beat, that *from no sensation* whatever, maximum palpitation develops within one second To assess the rate and rhythm it is helpful to ask the patient to represent them by tapping with his finger The manner in which the attack ends may be more difficult to establish some patients become accustomed to the palpitations and gradually fail to perceive them; others pass from a true paroxysm to sinus tachycardia without appreciating the change, and their description of the end refers to the gradual slowing down of the sinus rhythm.

Attacks may last from a few seconds to several weeks, but are usually

measured in hours, and rarely exceed three days. The speed ranges between 110 and 250 per minute, but is between 140 and 240 in 90 per cent. of cases, and between 150 and 200 in 50 per cent. (Campbell, 1947). Occasionally, however, much faster rates have been recorded For instance, in one of Bouveret's cases the heart rate was 300 per minute. If the heart is normal, as it is in 62 per cent of the supraventricular variety, there are usually no other symptoms apart from those provoked by anxiety; but if the attack is unduly prolonged, or the heart rate exceptionally rapid, congestive failure or angina pectoris may occur. If the heart is abnormal, however, as it is in 80 per cent of the ventricular variety, the rapid development of congestive heart failure is common With very rapid rates syncope is said to occur, and, in ischæmic heart disease, status anginosus. Physiologically, the effects depend upon the functional capacity of the heart to increase its output with tachycardia, and on its ability to stand up to the extra work imposed with minimal rest. At any given moment there must be a critical rate above which the cardiac output falls

SUPRAVENTRICULAR PAROXYSMS

As just indicated, both paroxysmal auricular and nodal tachycardia are most commonly encountered in healthy individuals, and have little more significance than ectopic beats or spontaneous fluttering of somatic muscle They are fifteen times more common than ventricular paroxysms. When attacks occur in patients with heart disease, the prognosis is not so good, and depends upon the nature and severity of the cardiac lesion, and the

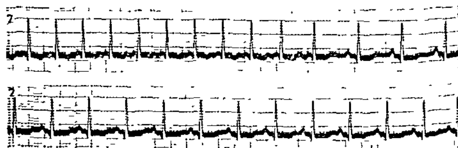


Fig 4 24—Paroxysmal auricular tachycardia terminated by means of mecholin.

speed and duration of the paroxysm. Even so, the mortality rate is only about 1 per cent.

A clinical diagnosis may be accepted if the spontaneous or induced beginning or end of an attack is proved to be abrupt; if the heart rate during a paroxysm exceeds 150 per minute and does not vary with effort, change of posture, atropine, amyl nitrite, carotid sinus (or eyeball) pressure, prostigmine, or mecholin; if any such measure terminates the paroxysm; if the duration of attacks is a matter of hours rather than one of minutes, days or

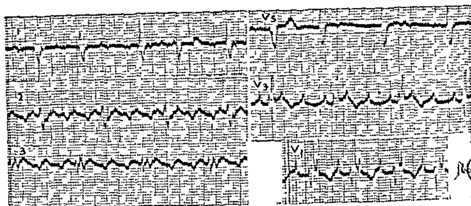
weeks; if the patient is relatively young, i.e. under 40 years of age, or was so when he had his first attack; if paroxysms have continued with variable frequency for more than five years; and if there is no evidence of organic heart disease or thyrotoxicosis. Electrocardiographic proof, however, which may require a record of the beginning or end of an attack, should be obtained whenever possible. Although only a rare chance will enable the onset to be registered, the end may be recorded in over half the cases by means of a continuous tracing while the attack is terminated by carotid sinus pressure or mecholin (fig. 4.24). If the attack is not terminated, such



Fig. 4.25—Paroxysmal auricular tachycardia blocked by carotid sinus compression

measures may yet serve to differentiate paroxysmal tachycardia from sinus tachycardia and from auricular flutter, for in paroxysmal tachycardia the heart rate is rarely altered, whereas in sinus tachycardia it is slowed, and in auricular flutter it is often abruptly halved. Occasionally, however, carotid sinus pressure may block paroxysmal auricular tachycardia (fig. 4.25).

Evans (1944) first presented evidence, based on lead CR1, suggesting that many cases which would ordinarily be interpreted as 2 : 1 auricular flutter might really be examples of paroxysmal auricular tachycardia with 2 : 1 A-V block, and that these two conditions were essentially the same. Certainly, paroxysmal auricular tachycardia may show varying degrees of A-V block (figs. 4.25 and 4.26a and b), and the auricular waves may be slowed by means of quinidine (figs. 4.27a and b) in the same way as flutter, there is also no doubt that the same patient may show all varieties of auricular rhythm, suggesting that they all depend upon a similar mechanism, and that the occurrence of auricular ectopics before or after a major attack (fig. 4.28) offers an obvious clue as to their essential nature. Indeed, Prinzmetal (1950) has now provided convincing evidence not only of the unity of paroxysmal auricular tachycardia and flutter, but also of auricular ectopic beats and auricular fibrillation, all four disturbances of rhythm depending upon the presence and behaviour of an ectopic irritable focus. Nevertheless, the clinical differences between paroxysmal tachycardia and flutter (not to mention auricular fibrillation and ectopic beats) are con-



(a)

II

PAROXYSMAL TACHYCARDIA RATE 120 1–1 RESPONSE

V1

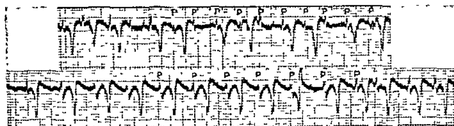
SUCCEEDED BY PAROXYSMAL AURICULAR TACHYCARDIA WITH 2–1 VEN RESPONSE

V1

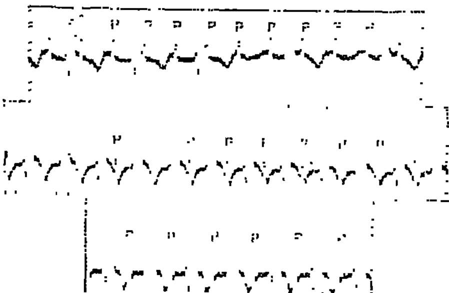
SPONTANEOUS RESUMPTION OF NORMAL RHYTHM

(b)

Fig. 4 26 (a), (b)—Two cases of paroxysmal auricular tachycardia showing varying degrees of spontaneous A-V block.



(a)



(b)

Fig 4 27 (a), (b)—Two cases of paroxysmal auricular tachycardia slowed by means of quinidine

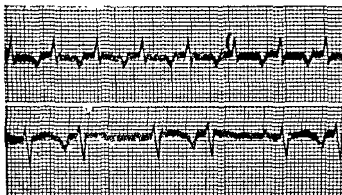


Fig 4 28—Paroxysmal auricular tachycardia followed by auricular ectopic beats

siderable (Campbell, 1945) and their separate identities should be preserved. Similarly, there can be no thought of not maintaining the separate identities of ventricular ectopics, ventricular tachycardia, and ventricular fibrillation, yet all three must depend on a similar physiological mechanism.

PAROXYSMAL NODAL TACHYCARDIA

Nodal paroxysms may be difficult to distinguish from auricular tachycardia when the rate is fast, unless the beginning of an attack can be recorded (fig 4 29a) At slower rates the electrocardiogram resembles fast

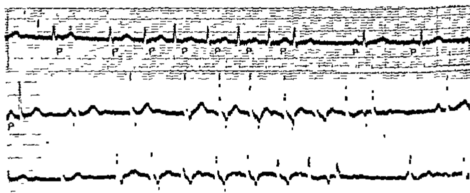


Fig 4 29 (a)—Paroxysmal nodal tachycardia beginning with a nodal ectopic beat.

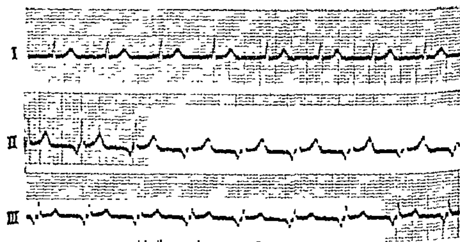


Fig 4 29 (b) Abnormal nodal type of rhythm with a *rate of 90 beats per minute.* The pacemaker is either in the A-V node or in adjacent auricular tissue, such as the mouth of the coronary sinus.

nodal rhythm Should an inverted P wave precede QRS, however, it may be impossible to determine whether the ectopic focus is in the A-V node or in adjacent auricular tissue, as in the slower form known as coronary sinus rhythm (fig. 4 29b).

Nodal tachycardia is commonly innocent and responds particularly well to carotid sinus pressure and to cholinergic drugs.

VENTRICULAR PAROXYSMS

Paroxysmal ventricular tachycardia is relatively rare, is usually associated with organic heart disease in patients between the ages of 40 and 70, and is

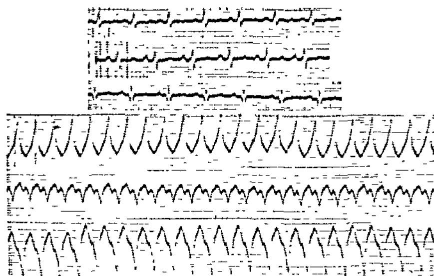


Fig 4 30—Paroxysmal ventricular tachycardia

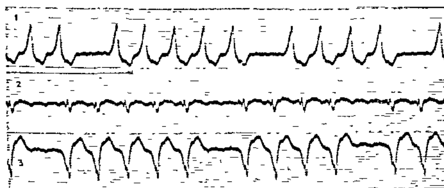


Fig 4 31—Auricular flutter with left bundle branch block

twice as common in men as in women It tends to arise in a badly damaged heart, as in heart failure from hypertension or from aortic valve disease; it may follow myocardial infarction, or succeed a Stokes-Adams fit, occasionally it is due to digitalis, in about 20 per cent of cases it is innocent

It has the same clinical features as the supraventricular variety, apart from the circumstances in which it occurs and its lack of response to carotid sinus pressure and to the cholinergic drugs; moreover, it is more frequently followed by congestive heart failure, and sometimes by ventricular fibrillation and sudden death. The prognosis is correspondingly grave.

Proof of the nature of the attack is obtained by electrocardiography (fig. 4 30); but difficulty may arise when supraventricular paroxysms or auricular flutter are complicated by previously established or functional bundle branch block (fig 4 31).

TREATMENT

Supraventricular paroxysms may be terminated by some mechanical trick already known to the patient, such as holding the breath; by carotid sinus or eyeball pressure in about 50 per cent of cases; and by the cholinergic drugs in 75 per cent. Devices discovered by the patient include the adoption of some particular posture, drinking cold water, forced breathing or breath-holding, compression of the abdomen, and self-induced vomiting.

The carotid sinus is located at the bifurcation of the common carotid artery at the level of the superior border of the thyroid cartilage. It should be firmly compressed for several seconds against the bodies of the cervical vertebræ by means of the observer's thumb, first on one side, then on the other, but never together. Bilateral eyeball compression is also carried out with the thumbs, should be sufficiently forceful to cause pain, and should be maintained for 3 to 5 seconds.

Of the cholinergic drugs, mecholin (acetyl-beta-methylcholine) is the most successful, and prostigmine the least unpleasant, in the doses employed, doryl (carbo-amino-acetylcholine) is less effective, and acetylcholine itself too drastic, besides being technically difficult owing to its rapid destruction in the bloodstream. Mecholin should be given intramuscularly or subcutaneously in a dose of 10 to 20 mg., and may be expected to work in about five minutes; prostigmine may be administered intravenously or intramuscularly in a dose of 1 to 2 mg., and has its maximum effect in about half an hour. Side-effects include urgent micturition and defæcation, colic, vomiting, sweating, flushing and faintness; but these are absent or slight with 1 to 1 5 mg. of prostigmine, and rarely severe with 10 mg. of mecholin. Should they prove too unpleasant and the object of the drug has not been achieved, they may be abolished at once by injecting 1 to 2 mg. of atropine sulphate intravenously; but this is obviously not advised unless absolutely necessary.

Should the cholinergic drugs fail to restore normal rhythm, quinidine or even digitalis may be successful In resistant cases of auricular tachycardia, digitalis may be used to maintain 2 : 1 or a greater degree of A-V block, in order to protect the ventricles. Bromide and phenobarbitone help to allay anxiety; and congestive heart failure, if it occurs, should be treated by the usual methods.

Ventricular paroxysms do not respond to the above measures, but may often be terminated by injecting 20 ml. of a 20 per cent solution of magnesium sulphate intravenously (Szekely, 1946), or by quinidine, 5 grains (0.32 G.), intravenously or in oral doses of 5 grains (0 32 G) two-hourly to a maximum of 40 grains (2.6 G) in one day, followed by 10 grains (0 65 G) two-hourly for four doses on the second day if the first attempt fails, and then by 15 grains (1 G.) two-hourly for three doses on the third day, if necessary. Intravenous procaine in doses of 5 to 10 ml of a 1 to 2 per cent solution may also be tried.

To prevent both types of attack, quinidine, 3 to 5 grains (0 2 to 0 32 G) t d.s., may be continued indefinitely, if well tolerated.

PAROXYSMAL TACHYCARDIA ASSOCIATED WITH PRE-EXCITATION

The condition first described as physiological bundle branch block with short P-R interval (Wolff, Parkinson and White, 1930) is probably due to premature excitation of one or other ventricle, usually the right, resulting from an anomalous connexion between the A-V node or right auricle and the right ventricle (Holzman and Scherf, 1932). Electrocardiography shows

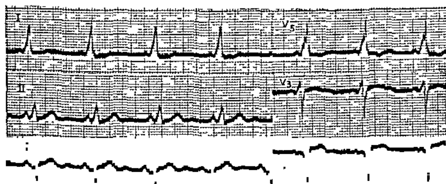


Fig 4 32 (a)—Pre-excitation

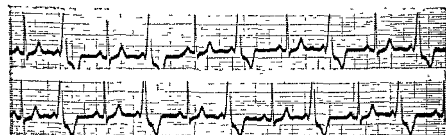
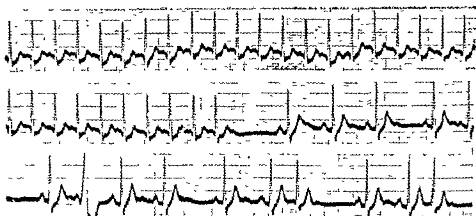


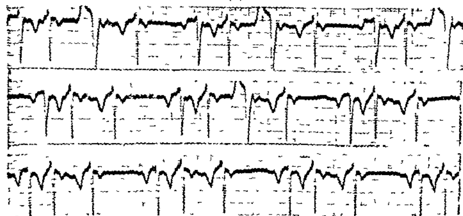
Fig 4 32 (b)—Alternating pre-excitation



(a)



(b)



(c)

Fig 4 33—Wolff-Parkinson-White Syndrome showing
(a) Paroxysmal tachycardia with normal QRS complexes (b) Paroxysmal tachycardia with widened QRS complexes (c) Auricular re-entry following the major attack

widening of the QRS complex, as in bundle branch block, but at the expense of the P-R interval which is shortened proportionally, the P-S interval, as measured from the beginning of P to the end of the QRS complex, remaining unchanged (fig 4.32a) The appearances usually resemble left rather than right bundle branch block. The anomalous pathway may be through the bundle of Kent (Wood, Wolferth and Geckeler, 1943, Kent, 1914), or through abnormal conducting fibres arising from the upper part of the bundle of His (Wolferth and Wood, 1933), such as those described by Mahaim (1931). The passage of the excitatory impulse down such an alternative pathway might well account for premature right ventricular stimulation Experimental short circuits of the kind envisaged were devised by Butterworth and Poindexter (1942), the classical appearances of the Wolff-Parkinson-White syndrome resulted.

The condition is congenital, occurs in both sexes equally, and is often unstable as shown by serial electrocardiograms; indeed, normal and abnormal complexes may alternate (fig. 4 32b). On the whole, normal conduction is encouraged by atropine, abnormal conduction by cholinergic activity (Duthie, 1946). The heart is otherwise normal in at least 70 per cent of cases, and heart disease when present is probably coincidental Pre-excitation is clinically and academically important on account of its association with paroxysmal tachycardia, and is easily overlooked because casual electrocardiograms may be normal Paroxysmal tachycardia occurs in 50 to 60 per cent of cases (Willius and Carryer, 1946), and is often closely related to effort Electrocardiograms obtained during attacks suggest that their mechanism may depend upon a circus movement, the impulse travelling down the bundle of His and back through the short circuit (fig 4 33a), or down the short circuit and back through the bundle of His (fig 4 33b), the former being more common Both types of paroxysm may occur in the same patient, as in the illustrations In this particular case the second type of paroxysm was provoked by mecholin, and before normal rhythm was resumed there was a period of transition in which abnormal P waves appeared immediately after certain QRS complexes (fig 4 33c), causing a single premature ventricular beat, and suggesting circus movement due to retrograde conduction through the bundle of Kent or similar structure, initial excitation having passed through the bundle of His Similar P waves may be seen in the upper half of figure 4 33b, but these fail to excite the ventricles Occasionally, attacks resemble auricular flutter or fibrillation, and the ventricular rate may be exceptionally fast A case described by Littmann and Tarnower (1946) had an irregular ventricular rate of 340 per minute

AURICULAR FLUTTER

Physiology. Auricular flutter in man was so named by Jolly and Ritchie (1910) after obtaining the first electrocardiographic records of the condition, and was attributed to a circus movement by Lewis (1918–20) The

excitatory impulse was believed to travel round a ring of auricular tissue, such as the mouths of the venæ cavæ, as proved possible by the physiological researches of Mines (1913). Rosenblueth and Ramos (1947) apparently confirm Lewis' views. Using a high-speed cinematograph technique, however, Prinzmetal (1950) has disproved this thesis, and has shown that auricular flutter and fibrillation, like auricular ectopic beats and paroxysmal auricular tachycardia, depend upon the presence and behaviour of an irritable focus in auricular muscle. The speed of the auricular beats ranges between 260 and 340 per minute, and its rhythm is regular. As the A-V node can rarely transmit impulses faster than 210 to 220 per minute, physiological heart block results, the ventricles usually responding to every second impulse. If the auricular rate is slower, however, and approaches 200 per minute, as it may under the influence of quinidine, the ventricles may be able to keep pace (Lewis, 1925) If vagal tone is increased, as by carotid sinus pressure, a greater degree of physiological block results, and an A-V ratio of 4 : 1 or so may be established. Sometimes the ventricular response is irregular

Clinical features, incidence, and etiology. Clinically, flutter should be suspected in any patient presenting a regular heart rate of 120 to 170 per minute, uninfluenced by effort, emotion, or change of posture, whether there are other indications of heart disease or not. The first heart sound often varies in intensity according to the time relationship between auricular and ventricular contractions (Harvey and Levine, 1948).

Flutter is a relatively uncommon but capricious rhythm, and may occur when least expected It is twice as common in men as in women, and its incidence increases with age, being rare under 30, and most frequent (88 per cent) between the ages of 40 and 70 It is very rare in otherwise normal individuals, it may complicate such diverse conditions as meningitis, pneumonia, cholecystitis, or carcinoma of the colon. In 90 per cent of cases, however, it is associated with organic heart disease, especially rheumatic, hypertensive, ischæmic or pulmonary, and may then precipitate or complicate congestive heart failure. According to Campbell (1947), angina pectoris develops in 25 per cent of paroxysms. Attacks are commonly transient, and have the same abrupt onset as paroxysmal tachycardia; but they tend to last longer, being measured in weeks rather than hours, and may occasionally persist for years Lewis (1937) described a case in a parson which had continued for 24 years.

Diagnosis is facilitated by carotid sinus pressure, which often causes abrupt temporary slowing of the ventricular rate, as described previously, whereas in sinus tachycardia slowing is commonly slight, and in paroxysmal tachycardia it is usually absent unless the attack is terminated Electrocardiography is advised in all suspected cases, however, and reveals a continuous series of rapid regular auricular "f" waves (fig. 4.34a) without intervening iso-potential periods. When there is 2 : 1 block, one "f" wave is more or less obscured by the QRS complex, so that the nature of the

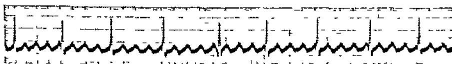


Fig 4 34 (a)—Auricular flutter with 4–1 A-V block

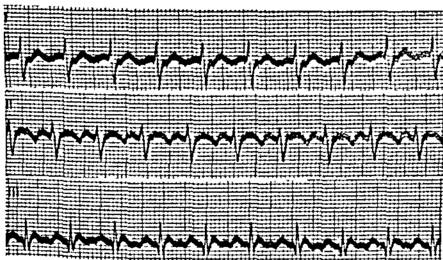


Fig 4 34 (b)—Auricular flutter with 2–1 A-V block

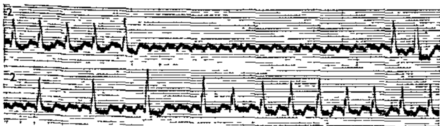


Fig 4 34 (c)—Auricular flutter clarified by means of carotid sinus compression

tachycardia may remain uncertain (fig. 4 34b). Carotid sinus pressure aids analysis by increasing the degree of block and so unmasking such hidden "f" waves (fig. 4.34c).

Treatment. The patient should be put to bed and treated with adequate doses of digitalis, beginning with 9 grains (0 6 G.) of the powdered leaf, followed by 6 grains (0 4 G.), and then by 3 grains (0 2 G.), at six-hourly intervals, and continuing with 2 grains (0 13 G) t.d s., until serial electrocardiograms show that auricular fibrillation has been established. The drug

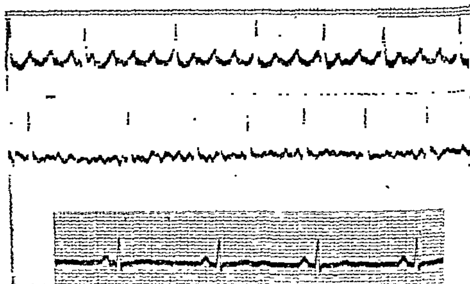


Fig 4 35—Auricular flutter treated with digitalis Auricular fibrillation is induced first on withholding the drug normal rhythm is resumed

is then withheld in the hope that normal rhythm may be resumed spontaneously (fig. 4.35). Electrocardiographic control is necessary because the slow irregular ventricular response which results from such doses of digitalis is no proof of auricular fibrillation under the circumstances. Adequate supervision is important owing to the heavy dose of digitalis usually required to induce fibrillation; and if toxic symptoms appear dangerous before this result is achieved, the attempt may have to be abandoned. The effect of digitalis is twofold, as already indicated· it encourages the irritable focus to assume the properties associated with auricular fibrillation; and by depressing conduction in the bundle of His, it slows the ventricular rate. It was hitherto believed that normal rhythm was resumed when the circus movement was broken by the head of the wave meeting a refractory tail (Lewis, 1925); for circus movement could not occur unless there was a gap of responsive tissue just ahead of the wave. Digitalis, either during its administration or when it was suspended, was thought to close the gap by having an unequal and favourable effect on conduction and on the

refractory period. Obviously, if conduction were quickened and the refractory period prolonged in auricular tissue, the hypothetical gap would close. Naturally, no drug has this effect, those quickening conduction also shortening the refractory period (like the cholinergic bodies) and *vice versa* (like quinidine). The action of digitalis is complicated by its cholinergic effect, the "f" waves are never retarded, but they may be accelerated, especially in those cases which are made to fibrillate (Wedd, 1924)

Quinidine should not be given alone to cases of flutter in the first instance, for by depressing the irritable focus and slowing the auricular rate, it may allow the ventricles to keep pace, rapid tachycardia resulting When auricular fibrillation has been established, however, the resumption of normal rhythm may be encouraged by quinidine in doses of 5 to 10 grains (0 32 to 0.65 G) two-hourly, to a maximum of 40 to 45 grains (2 5 to 3 G) in one day; or it may be given to resistant cases of flutter so long as the ventricular response is blocked by digitalis.

If flutter continues despite all efforts to break it, the patient should be kept on a maintenance dose of digitalis sufficient to control the ventricular rate; but the result is rarely satisfactory for short of digitalis intoxication, tachycardia due to 2 : 1 ventricular response is apt to develop on little provocation.

In all cases attention should be paid to any associated disease, cardiac or otherwise, and to combating congestive heart failure

AURICULAR FIBRILLATION

Physiology According to Prinzmetal (1950), two types of auricular contractions may be seen by means of a high-speed cinematograph in experimental auricular fibrillation (1) minute irregular contractions, which he has called M contractions, involving a small area of auricular wall (0 03 × 3 mm.), and (2) large rhythmic wave-like contractions (L contractions), which sweep across the auricle 400 to 600 times per minute, without pursuing a circus pathway Blocking a hypothetical circuit round the mouths of the venæ cavæ had no effect on these waves Direct auricular leads recorded by means of a cathode ray oscillograph showed very small M waves at 10,000 to 40,000 per minute, and large f waves corresponding to the L contractions. The M waves did not occur in flutter. Lewis's theory of circus movement appears to be untenable

At speeds of 320 to 380, electrocardiograms from chest leads placed over the right auricle show "f" waves which at times are regular and even as in flutter, and which at other times are irregular and uneven as in fibrillation (fig 4.36) At faster rates the "f" waves are always irregular in time and shape, and the ventricular response is commonly rapid and chaotic, varying between 100 and 200 per minute (fig. 4 37) Sometimes, and of course in treated cases, when there is partial auriculo-ventricular block, the ventricular rate is relatively slow. Occasionally there is complete



Fig 4.36—Lead CR1 showing coarse auricular fibrillation or impure flutter.

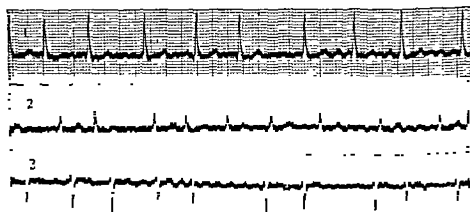


Fig 4 37—Auricular fibrillation

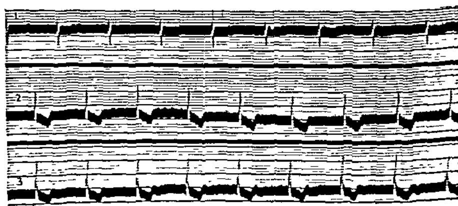


Fig 4 38—Auricular fibrillation with complete A-V dissociation due to digitalis

heart block: usually in cases treated with digitalis over a long period of time, and the ventricular rate is not only slow, but regular (fig 4 38)

Etiology. Auricular fibrillation is characteristically associated with mitral stenosis and toxic nodular goitre, and is usually permanent with the former and paroxysmal with the latter. It is not uncommon, however, in the later stages of hypertensive and ischæmic heart disease. On the other hand, it is rare in congenital heart disease, in bacterial endocarditis (2 per cent), in any form of active carditis in young people, in aortic valve disease (unless [illegible]

[illegible] over, auricular fibrillation may occur in patients with no other evidence of heart disease: it may complicate head injuries, meningitis, pneumonia, and other infections in rare instances, and it may even be found in apparently healthy persons The most important single factor determining the incidence of auricular fibrillation in those diseases that favour its occurrence is the advancing age of the patient.

Clinical features. Symptoms may be absent or negligible, or the patient may complain of palpitations. If the ventricular rate is very rapid, syncope or angina pectoris may result, as with flutter and paroxysmal tachycardia The mechanical inefficiency and nutritional hazards resulting from the rapid irregularity of the heart beat often lead to congestive failure when there is underlying heart disease; on the other hand, auricular fibrillation may be precipitated by congestive failure from other causes

Diagnosis The clinical diagnosis rests upon the recognition of a chaotic cardiac rhythm, i e. one without any semblance of order, and must be distinguished from sinus arrhythmia, from ectopic beats, and from auricular flutter. Sinus arrhythmia should be recognised by its relation to respiration, and ectopic beats by the perception of some fundamental order, but multiple auricular ectopic beats, especially when associated with sinus arrhythmia, and auricular flutter with an irregular ventricular response, may be most confusing. Electrocardiography is therefore advised in all suspected cases.

Treatment All cases in which the ventricular rate is accelerated should be treated with digitalis. When there is no urgency, a simple and safe method is to give powdered digitalis leaf, 3 grains (0 2 G.) t d.s on the first day, 2 grains (0 13 G.) t.d s on the second, and 1 grain (65 mg.) t d s. thereafter, until the ventricular rate is controlled Subsequently a maintenance dose of 1 grain (65 mg) b i d is usually sufficient When a quicker effect is desired, the method described for cases of auricular flutter is advised In urgent cases with very rapid ventricular rates and severe congestive heart failure, digoxin by the intravenous route may be preferable, but is not without danger, and should never be given in full doses to any patient who may have had digitalis within the previous six weeks, or who still shows a digitalis effect in the electrocardiogram The initial maximum dose is 1 5

mg., and this may be followed by 0.5 mg , and then by 0 25 mg , at intervals of not less than two hours and not more than six hours. In favourable circumstances the ventricular rate may be controlled within half an hour, an oral maintenance dose should then replace the later intravenous doses just recommended. Strophanthin may be used instead of digoxin; as Ouabain it may be given in an initial dose of 1 0 mg intra[illegible] y 0 5 mg., and then by 0 25 mg. six [illegible]
As strophanthin is all excre[illegible], it is preferable to digoxin when a cumulative [illegible] is not desired

Other preparations of digitalis may be given by mouth, the dose being calculated according to the following table of equivalent strengths·

Powdered digitalis leaf . . .	1 grain (65 mg)
Tincture of digitalis . . .	10 minims (0.6 ml.)
Digoxin	0.25 mg
Digitoxin (Nativelle's Digitaline) .	0.075 mg.

The practitioner is advised to become thoroughly familiar with a few reliable preparations Digoxin and digitoxin have the advantage of being pure crystalloids of fixed potency Digoxin appears to be excreted more quickly than digitoxin The tincture loses strength with the passage of time and when mixed with other drugs, and is therefore least reliable. The powdered leaf has been the standard preparation in this country for many years, but is being gradually displaced by digoxin A point of importance when calculating equivalent doses of different preparations is that the maximum single dose of the more rapidly excreted drugs, such as strophanthin and digoxin, is smaller than would be assessed by the table of equivalent strengths thus it is safe to give an average adult 9 grains (0.6 G.) of the powdered leaf as a massive single dose, and to follow it at six-hourly intervals by 6 grains (0.4 G), and then by 3 grains (0 2 G), but it is not safe to give 2 25 mg of digoxin, followed by 1 5 mg. and then by 0.75 mg, although its maintenance dose is 0 25 mg. twice daily. Massive oral doses of digoxin should not exceed 1 5 mg., 1 mg., and 0.5 mg. at six-hourly intervals

Toxic symptoms include anorexia, nausea, vomiting, diarrhœa, ectopic beats, nodal rhythm, heart block, paroxysmal tachycardia, and sudden death from ventricular fibrillation. Nausea and coupling due to ectopic beats are the best indications that the accumulated dose of digitalis is approaching dangerous concentration. Unfortunately, the worse the heart, the closer the therapeutic dose becomes to the toxic, the margin is never great. The vagal effects may be relieved by atropine.

The correct maintenance dose must be worked out for each individual receiving the drug; but it averages 0.5 mg of digoxin daily, ranging between 0 25 and 0 75 mg.

Attempts to restore normal rhythm with quinidine should be made in all cases in which there is no evidence of intrinsic heart disease, and especially

in cases of successfully treated thyrotoxicosis; also, perhaps, when auricular fibrillation is thought to have occurred prematurely or unexpectedly, having been precipitated by some passing infection, such as tonsillitis or pneumonia, or by some other factor which either no longer operates, such as pregnancy, or which is itself controllable, such as dental sepsis When fibrillation develops in the natural course of heart disease, however, e g in mitral stenosis or hypertensive heart disease, attempts to restore normal rhythm end in immediate or remote failure, and should therefore be avoided as the procedure is not without risk.

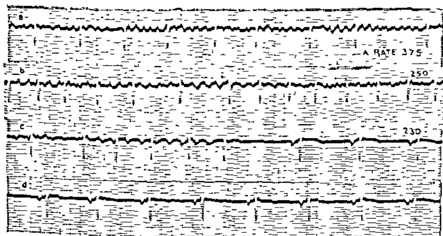


Fig 4 39—Auricular fibrillation treated with quinidine. The f waves slow down from 375 to 230 per minute before normal rhythm is restored.

Quinidine should be given by mouth in doses of 5 grains (0 32 G.), two-hourly, on the first day, followed by 10 grains (0 65 G.), two-hourly, on the second, and by 15 grains (1 G), two-hourly, on the third, to a maximum of 40 to 45 grains (2 6 to 2 9 G.) per day, the course being terminated immediately the rhythm returns to normal. A maintenance dose of 5 grains (0 32 G.) t d.s. is continued for a month in successful cases.

Quinidine depresses the activity of the irritable focus, retarding its periodicity and often abolishing it altogether (about 50 per cent of cases) As the "f" waves slow down (fig 4 39), they may assume the regularity of flutter, and if their speed approaches 200 per minute there is danger of a 1 : 1 ventricular response. Tachycardia so provoked by quinidine may be

not prejudice successful practical results.

Other complications of quinidine therapy include hypersensitivity and embolism. Hypersensitivity may result in generalised œdema, urticaria, purpura, fever, vomiting and collapse, although such symptoms are rare,

it is customary to give an initial trial dose of 3 grains (0.2 G.). Important systemic emboli occur in about 5 per cent of all cases in which normal rhythm is restored, and are due to the expulsion of left auricular thrombi. The risk is more or less proportional to the length of the period of fibrillation, and is greatly increased by congestive heart failure. Intracardiac thrombi are rare in thyrotoxic heart disease, even under the most unfavourable circumstances, owing to the rapid circulation associated with it. Pulmonary emboli also occur, but rarely prove troublesome.

VENTRICULAR FIBRILLATION

Faradic stimulation of the ventricles invariably induces inco-ordinated fibrillation of the muscle which usually persists after cessation of the exciting cause The heart muscle is unable to expel its contents and syncope

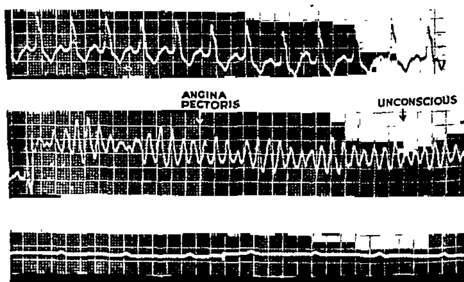


Fig 4 40—Ventricular fibrillation causing sudden death in a case of ischæmic heart disease

occurs abruptly. Spontaneous recovery may occur, especially in young healthy animals, but sudden death is the rule. When the heart is unduly excitable, as in asphyxia, digital pressure or gently scratching the surface of the ventricle with a pin may be sufficient to induce ventricular fibrillation (MacWilliam, 1887) Certain drugs may initiate the phenomenon, notably adrenaline, chloroform, and digitalis Coronary occlusion is also known to be an exciting cause.

Clinically, ventricular fibrillation is often responsible for sudden death, especially in ischæmic heart disease (fig 4.40), aortic stenosis, syphilitic aortic incompetence, diphtheritic carditis, and complete heart block. It also

explains sudden death following intravenous injections of digitalis, mercurial diurectics, adrenaline, and other drugs

Treatment is of little avail. The intracardiac injection of quinidine sulphate, 3 to 5 grains (0 2 to 0.32 G.), or of 5 to 10 ml of 1 to 2 per cent procaine, may be tried if circumstances are favourable. Quinidine may also be used as a prophylactic agent when the risk of ventricular fibrillation is great, e.g. following coronary thrombosis or in status anginosus.

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CHAPTER V

HEART FAILURE

HEART failure has been defined as a condition in which the heart fails to discharge its contents adequately (Lewis, 1933). The words may be applied logically to the heart as a whole or to one or other ventricle The adjective "congestive" is often added, and has come to mean heart failure with systemic congestion, i e with elevation of the systemic venous pressure and engorgement of the liver, with or without dropsy. Right ventricular failure has a similar meaning, but implies also that the left ventricle is relatively healthy Left ventricular failure is characterised by congestion of the lungs only

MECHANISM

The mechanism, and even the definition, of heart failure have been debated for over a century, and are still a source of controversy. The back-pressure theory, so well expressed by James Hope in 1832, which incorporates the idea of independent ventricular failure, maintains that when a ventricle fails to discharge its contents adequately, blood accumulates behind it, and the [illegible] nous system [illegible] s replaced by [illegible] ved that con- [illegible] behind, and who insisted that the heart failed as a whole. Before the second world war opinion reverted sharply to Hope's view, the arguments in its favour being well marshalled by Harrison (1935) and by Fishberg (1939); but the newer methods of investigation which provided much of the data upon which these arguments were based were crude, and subsequent technical refinements have disproved many of them The modern attitude has been shaped largely by the work of Cournand in the U S A., and of McMichael and Sharpey-Schafer in England

By means of intracardiac catheterisation these investigators have pro- [illegible] pressure minus the negative intrathoracic pressure) until a critical level is reached, after which any further rise of venous pressure results in "over-loading" and a fall in output (fig. 5.01) It is known that in patients with

severe anæmia a raised venous pressure is primarily a physiological adjustment which serves to maintain a high cardiac output, and that artificial alterations of the venous pressure results in changes of cardiac output in harmony with Starling's Law (Sharpey-Schafer, 1944) Should a further rise of venous pressure result in a lower cardiac output, the heart is said to be overloaded.

McMichael and Sharpey-Schafer (1944), after making further observations on the relationship between the right auricular pressure and the

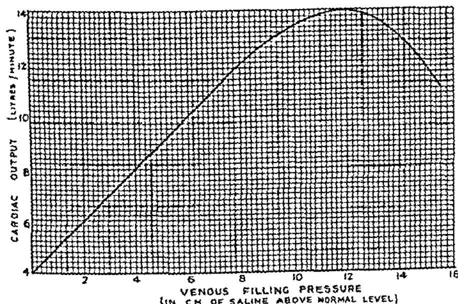


Fig 5 01—Relationship of cardiac output to venous filling pressure (Starling's curve)

cardiac output in health and disease, put forward the hypothesis that elevation of the venous pressure is primary in all forms of congestive heart failure, and may be regarded as a compensatory mechanism designed to increase the cardiac output For a time, and particularly in certain hyperkinetic circulatory states (e g anæmia, arterio-venous aneurysm) in which the cardiac output is high, the mechanism is successful, but sooner or later overloading occurs According to this hypothesis, congestive heart failure might be defined as a state in which the heart can only maintain the requisite output by means of abnormal elevation of the venous pressure, or as a state in which such elevation of the venous pressure has already resulted in overloading The second clause defines a more advanced condition than does the first, and it may well be objected that the first does not in fact define congestive failure at all, but a compensated state which has no right to the title. Congestive heart failure is a clinical syndrome characterised by elevation of the venous pressure and distension of the liver, with

or without dependent œdema, the result of some cardiac fault. If these manifestations can be demonstrated when the heart is not yet overloaded, the definition must be allowed

The clinical facts are these. In anæmia, arterio-venous aneurysm, and extensive active Paget's disease of bone, elevation of the venous pressure without demonstrable distension of the liver is commonly associated with a high cardiac output. If the venous pressure is raised further, the output usually rises; if it is reduced, the output usually falls. Such behaviour has been labelled "high output failure", and is covered by the first of the two definitions given above Cervical venous pulsation is rarely visible above clavicular level when the patient reclines at an angle of 45 degrees; in other words it is rarely more than 3 or 4 cm above the sternal angle in this position When the venous pressure is raised more conspicuously, the liver becomes palpable and the heart is probably overloaded In thyrotoxicosis, high cardiac outputs are maintained chiefly by means of tachycardia. Clinical elevation of the jugular venous pressure is associated with hepatic enlargement and is only seen when the heart is overloaded. The cardiac output is then usually low. In pulmonary heart disease secondary to emphysema, elevation of the venous pressure is commonly associated with hepatic engorgement and with a moderate increase in cardiac output The latter usually falls when the venous pressure is further raised, but it also falls when the venous pressure is lowered In most other forms of heart disease, elevation of the venous pressure is associated with hepatic engorgement and with a low cardiac output, further elevation of the venous pressure results in further reduction of the cardiac output

Clinicians are therefore likely to favour the view that congestive heart failure is a state in which the heart is overloaded, i.e a state in which further elevation of the venous pressure causes a reduction in cardiac output. The best clinical indication of this may be demonstrable distension of the liver. Whatever the final verdict on this vexed question, it is certainly true to say that in congestive heart failure the venous pressure rises primarily behind the chamber chiefly involved, i e. in the left auricle and pulmonary veins in mitral stenosis and left ventricular failure, in the right auricle and systemic veins in tricuspid valve disease and right ventricular failure. Moreover, in mitral stenosis and left ventricular failure, secondary elevation of the systemic venous pressure is the rule sooner or later, whether this be regarded as evidence of right ventricular failure or otherwise.

CAUSES OF HEART FAILURE

The heart may fail because it is overburdened by a raised ventricular pressure or by a raised cardiac output, or because the health of the myocardium is impaired by inadequate or faulty nutrition, metabolic disorder, intoxication, or intrinsic disease High outputs are tolerated better than high pressures; but myocardial ill health is probably even more important.

Contributory factors include physical effort, obesity, anxiety, mental stress, disturbances of rate or rhythm, infection, fever, extremes of temperature, and pregnancy; but all these are better expressed in more fundamental terms: for example, infection may increase the cardiac output and impair the health of the myocardium; anxiety and cold may raise the blood pressure; and so forth

Viewing the subject in this way, it should be clear that a high cardiac output is no more incompatible with heart failure than is hypertension, that a heart capable of pumping ten litres of blood per minute is not necessarily better than one capable of maintaining a diastolic blood pressure of 140 mm. of Hg. Each is a measure of part of the total cardiac work performed, neither alone is a sufficient measure of cardiac efficiency, although their behaviour under certain experimental conditions may be Moreover, the signs and symptoms of heart failure are largely due to alterations of pressure and volume in the pulmonary or systemic venous systems. In left ventricular failure, for example, the redistribution of volume is the result of a short-lived discrepancy between left and right ventricular outputs Although the balance must be restored quickly, the consequences cannot be rectified until the process is reversed It should again be clear that such disturbances cannot be detected by casual estimations of the right ventricular output

LEFT VENTRICULAR FAILURE

When the left ventricle fails to discharge its contents adequately, blood accumulates in the pulmonary circulation, and the pressure rises in the left auricle and pulmonary veins

ETIOLOGY

Left ventricular failure may result from any disease which imposes an undue burden on the left ventricle or which interferes with its health These diseases include systemic hypertension from any cause, aortic valve disease, and myocardial infarction In systemic hypertension, the left ventricle may fail either because it is unable to meet the stress imposed upon it, or because it is enlarged so greatly that it cannot obtain sufficient nourishment. As the nutritional demands of an individual muscle fibre depend upon its cubic volume, and the nutritional supply is limited by its surface area, there is an increasing discrepancy between the two as the muscle enlarges, which sooner or later becomes critical (Gross and Spark, 1937) In acute nephritis and malignant hypertension, a rapid rise of blood pressure may cause left ventricular failure before there has been appreciable hypertrophy of muscle, on the other hand, in long-standing cases of essential hypertension with gross enlargement of the left ventricle, failure may occur even though the blood pressure has fallen to within normal limits, failure then being attributed to nutritional breakdown In aortic valve disease, in addition to these two factors, there may be further interference

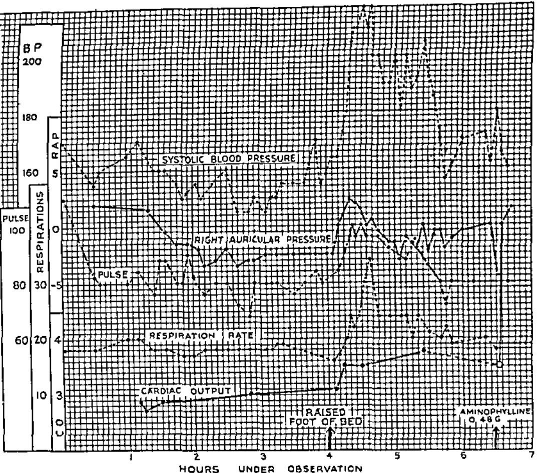
with nutrition as a result of poor coronary filling, due to a low mean blood pressure in aortic stenosis, and to obstruction of the mouths of the coronary vessels in syphilitic aortic incompetence. The cause of failure in uncomplicated ischæmic heart disease with myocardial infarction is due entirely to interference with ventricular nutrition resulting from coronary occlusion.

CLINICAL FEATURES

The symptoms of left ventricular failure are undue breathlessness on effort, orthopnœa, paroxysmal cardiac dyspnœa, and acute pulmonary œdema. The findings include bilateral basal pulmonary râles, diminished vital capacity and lung volume, radiological evidence of pulmonary congestion and hydrothorax, and prolongation of the pulmonary circulation-time The diagnosis is supported by gallop rhythm, pulsus alternans and Cheyne-Stokes breathing, and is confirmed by the demonstration of a suitable cardiovascular disease, e g systemic hypertension, aortic valve disease, or myocardial infarction

Undue breathlessness on effort. Breathlessness on effort is physiological. When a patient complains of breathlessness, he means that he is winded by physical work that did not distress him previously: the symptom, *per se*, does not, of course, necessarily indicate heart disease, other common causes including psychoneurosis, obesity, chronic bronchitis, asthma, emphysema and anæmia. Breathlessness due to left ventricular failure depends upon pulmonary congestion, which both reduces the vital capacity and reflexly stimulates respiration.

Orthopnœa, paroxysmal cardiac dyspnœa, and pulmonary œdema. As these three conditions depend on variations of the same fundamental mechanism, they are considered together. When a patient adopts the upright or sitting position in order to breathe comfortably, he may be said to have *orthopnœa* Although an almost constant sign of left ventricular failure, it is by no means pathognomonic; for it may be found in severe mitral stenosis, bronchial asthma, and in pericardial effusion. The vital capacity is reduced in all these conditions, and is greater in the upright than in the horizontal position; but its relationship to orthopnœa is not necessarily direct. Moreover, its increase in the erect position is greater than can be explained by descent of the diaphragm The discrepancy is due to concomitant changes in the pulmonary circulation, the amount of blood in the lungs being greater, perhaps by as much as 500 ml., in the horizontal than in the erect position (McMichael, 1939). The redistribution of blood depends upon the geographical relationship of the auricles to their respective venous systems. As the right auricle is nearer the head than the feet, the pressure within it rises when the body is tilted head up, owing to the influence of gravity. The right ventricle responds according to Starling's Law and pumps more blood into the lungs in the horizontal than in the vertical position The pressure within the left auricle, however, which is situated more or less in the centre of the lungs, is not directly influenced by gravity, and the left


BP
200
180
160
PULSE
100
80
60
RESPIRATIONS
30
20
10
RAP
5
0
-5
4
3
CO
SYSTOLIC BLOOD PRESSURE
RIGHT AURICULAR PRESSURE
PULSE
RESPIRATION RATE
CARDIAC OUTPUT
RAISED FOOT OF BED
AMINOPHYLLINE 0.48 G
1
2
3
4
5
6
7
HOURS UNDER OBSERVATION

ventricular output does not, therefore, immediately keep pace with th the right. Only when the left auricular pressure rises proportion: owing to an increased volume of blood in the pulmonary venous sy: will the balance be restored As patients with left ventricular failure al: have pulmonary congestion, the extra engorgement which results adopting the horizontal position may prove critical and may excite res tory reflexes which provoke dyspnœa.

Paroxysmal cardiac dyspnœa usually occurs at night. The patient av with a feeling of suffocation, and sits bolt upright gasping for breat may climb out of bed and open a window, or walk about in an agitated In cases of simple orthopnœa this behaviour brings immediate relief; b paroxysmal cardiac dyspnœa the feeling of suffocation increases, an struggle for breath lasts for ten to twenty minutes Coughing and whe are commonly associated (*cardiac asthma*), and the patient may com of palpitations, faintness, or substernal tightness The skin is cyanosed and cold, indicating profound vasoconstriction, and sweating be profuse. The blood pressure and venous pressure are both ra Attacks usually subside spontaneously, but may be repeated nightly intervals of days or weeks In more severe cases pulmonary œdema deve Widespread crepitations may be heard over the lungs and quantiti frothy pink or white watery fluid are expectorated.

Such attacks may sometimes be provoked by effort or by a rigor. are easily induced experimentally in susceptible subjects by raising e the venous pressure or the blood pressure by artificial means (fig. The mechanism probably depends upon acute discrepancy between and left ventricular outputs, so that both the pressure and volume of b in the pulmonary circulation reach critical levels. Measurements of pre changes by means of an indwelling cardiac catheter in spontaneous turnal attacks indicate that the venous pressure may rise before the b pressure. When attacks are induced by raising the venous pressure cardiac output may rise. Thus, although the heart is said to be failir may in fact be performing more work than usual, both with respe blood pressure and output. The laboured breathing may be due in to the extra effort required to inflate and deflate a turgid lung, intrapleural pressure showing greatly increased fluctuations (Heyer e 1948)

Spontaneous termination of the attack may be due to reduction of auricular pressure by adoption of the upright posture, or possibly to o loading of the weaker right ventricle, so that the left has a chance to rec and restore the *status quo* The difference between paroxysmal car dyspnœa and acute pulmonary œdema is chiefly one of degree, transuda of fluid from the capillaries into the alveolar spaces occurring when intravascular hydrostatic pressure is sufficiently high or when other fac influence the fluid balance in favour of the tissues.

Bilateral basal pulmonary râles and hydrothorax. Basal râles, diminis

air entry into the lower lobes, and some impairment of the percussion note at the bases are usual in left ventricular failure. Bedford and Lovibond (1941) found that hydrothorax was a common complication of pulmonary congestion from left ventricular failure, and that, although often bilateral, tended to be more marked on the left side. Its occurrence may depend upon the fact that the visceral pleura is drained by the pulmonary rather than by the bronchial veins (Miller, 1937)

Reduction of the vital capacity and lung volume. The vital capacity is reduced by an amount equivalent to the extra quantity of blood distending the pulmonary circulation, it is reduced much more if there is pulmonary œdema or a large hydrothorax as well, and by a further few hundred ml according to the degree of cardiac enlargement. Readings of 1,000 to 1,500 ml. are common, and may be as low as 500 ml. when there is pulmonary œdema or hydrothorax.

The lung volume is reduced proportionately, the residual air remaining unchanged. This at once distinguishes the condition from emphysema in which a low vital capacity is associated with a normal lung volume and increased residual air



Fig 5 03—Pulmonary congestion in left ventricular failure (case of syphilitic aortic incompetence)

Radiological signs of pulmonary congestion Although the râles revealed by auscultation are most pronounced at the most dependent parts of the lung, the increased opacity seen in skiagrams is hilar, and is due to engorgement of the pulmonary vessels (fig 5 03) During attacks of acute pulmonary œdema a fleecy mottling spreads out from the hilum on both sides (fig 5 04) Hydrothorax may also be revealed by X-rays, perhaps when unsuspected clinically. Confirmatory evidence of left ventricular failure may be obtained by noting the size and shape of the heart shadow.

Prolongation of the pulmonary circulation time The normal arm-to-tongue circulation time, as measured by decholin or saccharin (page 13), averages 13.5 seconds, but ranges between 9 and 18 seconds. As the time taken by the substance to travel from the left ventricle to the tongue may be neg-

(a) From left ventricular failure

(b) From mitral stenosis

Fig. 5.94—Acute pulmonary [illegible]

lected, and as the journey from the antecubital vein to the right auricle takes only two or three seconds (Blumgart and Weiss, 1927), the total arm-to-tongue time is governed chiefly by passage through the lungs Using radium C intravenously, which can be detected at any given point in the circulation by means of a special radio-sensitive instrument, Blumgart and Weiss also showed that when the systemic venous pressure is raised in congestive heart failure, the delay between the antecubital vein and the right auricle does not exceed five seconds, even in gross cases It follows that with pure right ventricular failure the arm-to-tongue circulation time should not exceed 23 seconds and should often be within normal limits, in fact this is so. On the other hand, in left ventricular failure the average time is 30 seconds (Wood, 1936), and may be much longer The delay is due to pulmonary congestion and occurs presumably on the venous side

The arm-to-lung time. The arm-to-lung time, as measured by ether or amyl acetate (page 13), is said to be helpful in distinguishing primary left from pure right ventricular failure, if the total arm-to-tongue time is also known When the delay is proximal to the heart, as in pure right ventricular failure, the arm-to-lung time is delayed as much as the arm-to-tongue time, on the other hand, if there is further delay in the pulmonary veins, as in primary left ventricular failure, the arm-to-tongue time is disproportionately prolonged. Although theoretically this test might seem helpful, in fact it is rarely so for two reasons: first, because the end-point in the lung, both with ether and amyl acetate, is often unreliable and indefinite, and second, because it is easier and no less accurate to allow 1 to 5 seconds for delay proximal to the heart according to the degree of systemic venous engorgement.

GALLOP RHYTHM

When the rhythm of the heart sounds has three instead of two beats per musical measure or bar, or when the metre of the heart beats has three instead of two syllables per poetical foot, one may properly speak of triple rhythm The term, therefore, covers all varieties of cadence in which three heart sounds are heard. Gallop rhythm, on the other hand, should have a stricter meaning, and should be applied only to specified forms of triple rhythm as explained subsequently

Mechanism Phonocardiography proves that there are really four normal heart sounds, the auricular or presystolic sound (sometimes known as the fourth heart sound) associated with auricular systole and late ventricular distension, the first heart sound due to mitral and tricuspid valve closure and [illegible]

these sounds is thus composed of at least two and at most four elements Although these elements may not be strictly synchronous, they are sufficiently so, as a rule, to produce but one obvious sound to the human ear.

On more careful analysis, however, they may often be separated sufficiently to be detected individually by auscultation, and we may then speak of split sounds. The word "split" describes the sound well, and also indicates the mechanism of its production The term "reduplication" is often used instead, but has less to recommend it, for it bears an accidental onomatopœtic resemblance to the sound of presystolic gallop, and it is illogical to apply a word that means doubling to an act of division. Split sounds do not give the cadence of triple rhythm because of the close proximity of the separated elements.

The "extra" sound that is responsible for triple rhythm is usually an exaggerated auricular sound, the third heart sound, or a summation of the two Occasionally it is an additional systolic sound of unknown origin.

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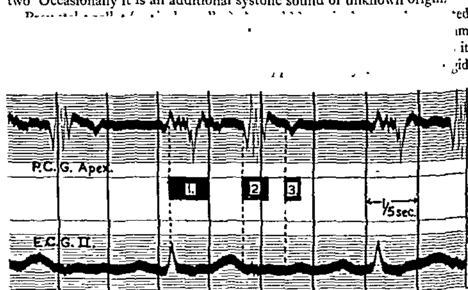


Fig 5 05—Phonocardiogram showing a normal third heart sound
(*By courtesy of Dr F D H Cowen*)

wooden stethoscope or with the naked ear, so that tactile and aural senses may be allied The presystolic sound is soft and dull, and is usually localised to the region of the apex beat In this situation it is pathognomonic of left ventricular stress Occasionally it is heard best at the left border of the sternum, when it may denote right ventricular stress. If the P-R interval is sufficiently prolonged, the auricular sound may fall in mid or early diastole; if the heart rate is fast, its true relation to the first or second heart sound cannot be determined clinically, unless transient slowing is induced by means of carotid sinus compression Presystolic gallop is never heard when there is auricular fibrillation

Normal third heart sound When the "extra" sound occurs shortly after the second heart sound, giving the metre of a dactyl (– u u), it may represent a normal or abnormal third heart sound (fig 5.05) The normal third heart sound was well described by Gibson (1907) It is soft, low pitched, and

usually accompanied by a palpable shock, it is more or less localised to the apex beat, varies in intensity with respiration, and is accentuated when the subject lies on the left side, especially if the venous pressure is raised by pressing on the abdomen. It may be heard in the great majority of children (but not in infants), in about 50 per cent of young adults, occasionally in the middle-aged, and rarely in the elderly. Phonocardiography shows that the third heart sound synchronises with the latter half of the descending limb of the "v" wave of the jugular phlebogram, and therefore with the period of rapid ventricular filling (Ohm, 1913) It is attributed to sudden distension of the left ventricle at this time

Protodiastolic gallop. Abnormal third heart sounds are common in mitral stenosis, constrictive pericarditis and in advanced hypertensive or ischæmic heart failure (protodiastolic gallop), especially when there is auricular fibrillation. The age and clinical condition of the patient emphasise their significance.

Summation gallop. Summation of the auricular and third heart sounds can only occur when there is tachycardia or when the P-R interval is sufficiently prolonged. With tachycardia the metre may seem to be anapaestic (u u –), dactylic (– u u), or amphibrachic (u – u), according to the fancy of the listener; for the "extra" sound occurs in mid-diastole Summation sounds have no clinical significance if they disappear when the heart is slowed by carotid sinus compression (summation gallop), on the other hand, such slowing may reveal an auricular sound or a normal or abnormal third heart sound.

Extra systolic sounds. It is not uncommon for an extra sound to occur during ventricular systole There are three varieties – the systolic click of left-sided pneumothorax, "lesser systolic clicks" possibly associated with pleuro-pericardial adhesions, and a third type in which the extra sound is dull and muffled, and in no way like a click. Patients with partial left-sided pneumothorax may complain of a loud clicking or bubbling noise synchronous with the heart beat It may be so loud that it can be heard at a distance of several feet from the patient, it varies markedly with respiration and with change of posture, and is always transient. It is occasioned by the activities of bubbles of air between the heart and surrounding structures, and only occurs when the pneumothorax is small, so that clinically it is a late development, appearing when most of the air has been absorbed (Scadding and Wood, 1939) Lesser systolic clicks are heard from time to time in subjects who are perfectly well, and according to Gallavardin (1913) may depend upon pleuro-pericardial adhesions In these cases the extra sound resembles a click, but is not so impressive, nor so variable, as that associated with left-sided pneumothorax. It may last for weeks, months or years, and may come and go without apparent reason. The third type (systolic gallop) is distinguished from greater and lesser systolic click by the character of the extra sound, which is dull and muffled Its mechanism is not yet understood It is uncommon, and when heard may be dis-

regarded, for it occurs in apparently healthy persons It should be distinguished from the widely split first sound of bundle branch block.

Note on nomenclature Introduced by Professor Bouillaud, analysed and popularised by Potain (1876), the term gallop rhythm originally referred to that variety of triple rhythm which denoted impending or actual left ventricular failure, and in the presence of tachycardia is "marvellously adapted to the sound it designates" But by 1900 Potain had extended the meaning of the bruit de galop to include presystolic, protodiastolic, and systolic varieties, attributing these different metres to the same factors that are to-day held responsible Thus historically it is not incorrect to regard gallop rhythm and triple rhythm as synonyms, but there is an advantage in excluding certain types of triple rhythm from the cadences embraced by the bruit de galop Thus it is preferable and customary to speak of presystolic (auricular), protodiastolic, systolic, and summation gallops on the one hand; and of systolic clicks, the normal third heart sound, and the triple rhythm of mitral stenosis on the other

PULSUS ALTERNANS

Pulsus alternans (Traube, 1872) is characterised by a regular rhythm in which the pulse beats are stronger and weaker alternately It may be detected by palpation or more easily by sphygmomanometry, there being a difference of 5 to 20 mm of mercury in the systolic pressure between

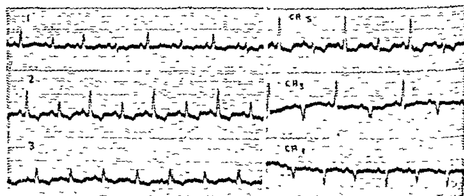


Fig 5 06—Electrical alternation in a case of malignant disease involving the pericardium pulsus alternans was present

alternate beats It may be found in association with left ventricular failure, toxic carditis, paroxysmal tachycardia or auricular flutter. Clinically, alternation may be maintained as long as the heart is labouring, occasionally for as long as two or three years. Latent alternation may become manifest when the heart beats faster. Experimentally, under favourable conditions, e g when the heart is poisoned by certain drugs including digitalis, when it is

made to beat very fast, or when its blood supply is curtailed, short periods of alternation may follow a premature ectopic beat (Mackenzie, 1907–8) or a dropped beat (Hering, 1908). Sphygmograms show that pulsus alternans may begin abruptly, either with an unusually large beat or with a small beat (Lewis, 1925), and that the sum of a large and small beat equals the sum of two normal beats (Gaskell, 1882). When the cardiac impulse appears to alternate in strength, the peripheral pulse may behave concordantly or discordantly, i.e. the larger pulse beat may be associated with the stronger or with the weaker cardiac impulse respectively (Hering, 1908)

No thoroughly satisfactory hypothesis has been evolved to explain pulsus alternans. It is generally believed that fewer muscle fibres contract with the weaker beats than with the stronger, owing to the development of a state of partial refractoriness (Lewis, 1925) fibres which do not contract with one beat, recover in time for the next, other fibres which contract with the first beat are still refractory and therefore unready for the second In other words, there is a state of 2 . 1 partial ventricular response But if this were true, all the beats should be weaker than normal, the hypothesis does not explain the stronger beats. Another suggestion is that pulsus alternans depends upon a disorder of ventricular relaxation, for the ventricles hold more blood with the stronger beats and less with the weaker (Straub, 1917)

Pulsus alternans should not be confused with electrical alternation (fig 5 06), nor with coupled beats due to premature systoles Electrical alternation is sometimes associated with pulsus alternans, however, as in the case illustrated

CHEYNE-STOKES BREATHING

Periodic breathing was described by Cheyne (1818) in what was probably a case of hypertensive heart failure with right hemiplegia "For several days his breathing was irregular, it would entirely cease for a quarter of a minute, then it would become perceptible, though very low, then by degrees it became heaving and quick, and then it would gradually cease again this revolution in the state of his breathing occupied about a minute" Stokes (1854) connected the phenomenon with serious heart disease

Mechanism Cheyne-Stokes breathing may be induced experimentally by hyperventilation, especially in the presence of anoxia Over-breathing washes out carbon dioxide, and the ensuing apnœa is due to carbon dioxide lack. During the apnœic phase there is progressive anoxæmia until re-accumulation of carbon dioxide excites the respiratory centre, and breathing is resumed During the dyspnœic phase carbon dioxide is again washed out, and the cycle repeats itself Anoxæmia and depression of the respiratory centre favour the production of Cheyne-Stokes breathing. The administration of carbon dioxide abolishes, the giving of oxygen diminishes and modifies, the periodicity The exact mechanism is unlikely to be understood until tissue chemistry is more advanced, especially that relating to the

respiratory centre. The crescendo character of the dyspnœic phase may be partly due to time-lag: when respiration starts, and carbon dioxide in the blood entering the lungs is blown off, blood which has already passed the pulmonary capillaries must have a higher carbon dioxide content than that which was required to galvanise the respiratory centre into action; this takes 5 to 10 seconds to reach the respiratory centre in normal subjects, and an average of about 20 to 25 seconds in patients with left ventricular failure.

Clinical features Periodic breathing may result from a cerebral lesion, e g. a head injury or a cerebral vascular accident, or from left ventricular failure, usually in patients with hypertensive or ischæmic heart disease, when sclerosis of cerebral vessels may be associated.

The cerebral type is characterised by a rise of blood pressure and pulse rate during the dyspnœic phase (Eyster, 1906); in patients with left ventricular failure, the central venous pressure and blood pressure rise during dyspnœa, the pulse rate and fore-arm blood flow during apnœa (Sharpey-Schafer, 1948). Rhythmic variation in the size of the pupils may also be observed: they dilate during dyspnœa and contract during apnœa

Cheyne-Stokes breathing is exaggerated by anything which further depresses the respiratory centre, e.g. by morphine, barbiturates, or natural sleep It may cause insomnia by waking the patient at the height of the dyspnœic phase

RIGHT VENTRICULAR FAILURE, CONGESTIVE HEART FAILURE

When the right ventricle fails to discharge its contents adequately, the pressure in the right auricle and the venæ cavæ rises, the liver becomes enlarged and tender, and dependent œdema usually develops

ETIOLOGY

Right ventricular failure may result from massive pulmonary embolism, subacute or chronic pulmonary heart disease, pulmonary stenosis, atrial septal defect, or beri-beri

The term congestive heart failure is preferable when systemic congestion complicates mitral stenosis, left ventricular failure, rheumatic or other forms of carditis, thyrotoxicosis or other hyperkinetic circulatory states (except those mentioned above), serious abnormalities of rhythm, patent ductus arteriosus, or other diseases affecting the heart as a whole. Failure in mitral stenosis is considered more fully on page 293; it is a mixture of pulmonary congestion, due to a left-sided lesion, and right ventricular failure.

CLINICAL FEATURES

be employed as a check. Inspection of the cervical veins should be carried out with the subject horizontal or inclined at an angle of 30, 45, 60 or 90 degrees, whichever position is most favourable. Venous pulsation may be distinguished from arterial in several ways. It is diffuse and undulant, at least two waves being seen to each heart beat (except in certain special circumstances); whereas arterial pulsation is local, abrupt and single If the jugulars are compressed at the root of the neck, venous pulsation ceases above this level, whereas the carotids continue to beat. Abdominal compression increases the height and amplitude of jugular pulsation, but has no effect on the carotids. The extent of cervical venous pulsation varies greatly according to the position of the patient, whereas carotid pulsation scarcely alters. Finally, the upper level of jugular pulsation may be seen to vary with respiration, moving down with inspiration and up with expiration The mean vertical height of this upper level above some arbitrary reference point such as the sternal angle should be measured in centimetres. The venous pressure may then be recorded in cm. above the sternal angle, with the patient at a known inclination. In normal subjects inclined at 45 degrees cervical venous pulsation is not seen at all, but it may appear in the supraclavicular fossa at 30 degrees, and may be 1 to 3 cm. above the sternal angle in the horizontal position



Fig 5 07—Photograph showing distension of the external jugular vein in a case of congestive heart failure

Examination of the external jugular veins may also be helpful If one of these vessels is constricted by the finger at the root of the neck, a column of blood distends the upper part of the vein, on removing the finger the vein collapses With the patient propped up at an angle of 45 degrees, complete collapse of the vein at the root of the neck denotes no rise of venous pressure; on the other hand, if the venous pressure is raised, only the upper part of the vein collapses, and it is easy to see the level at which pulsation ceases in the dilated lower part (fig. 5.07). In assessing the venous pressure by observing the external jugulars, it is important to make sure

they are pulsating, for it is not unusual (nor abnormal) to find one or both of them dilated, but not pulsating, as a result of constriction at the point where they pierce the deep cervical fascia.

The amplitude of venous pulsation is also worth noting; for in pericardial effusion and chronic constrictive pericarditis it is diminished, and in tricuspid incompetence it is enhanced

Occasionally the venous pressure is so high that pulsation, which only occurs at the top of the column, cannot be seen at all. If the veins are not obviously distended the raised venous pressure may then be overlooked, or if recognised may be attributed to superior vena cava obstruction. Intracardiac catheterisation provides a valuable method of arriving at the truth. Superior vena cava obstruction is often only partial, and the sudden fall in venous pressure, as the catheter slips through the constriction, is diagnostic.

Observation of cervical venous pulsation is still incomplete without noting its quality and its relationship to the arterial pulse. The "a", "c" and "v" waves of the jugular phlebogram may be difficult to detect with precision, but it is usually possible to make out two waves and two troughs, and it may be quite easy to time the main wave or trough.

A single abrupt collapsing type of venous pulsation in presystole denotes an exaggerated auricular "a" wave and is no evidence of failure. It alters little with change of posture, may be palpated (when it feels like a venous water-hammer), and is sometimes transmitted to the liver as described by Mackenzie (1902) It is most conspicuous in tricuspid stenosis, but may be associated with any condition which gives rise to powerful right auricular contraction (commonly cases with high right ventricular pressures and tall P waves) Cannon waves, due to right auricular contraction against a closed tricuspid valve (as in heart block), look very similar, but occur during ventricular systole.

In tricuspid incompetence the main venous wave is systolic and is usually powerful and prolonged The normal depression following "c", due to the sucking action caused by descent of the atrio-ventricular septum, is replaced by a wave of high pressure transmitted directly from the right ventricle thus the "c" and "v" waves become more or less fused. When there is auricular fibrillation, the single forceful systolic venous wave so produced may be mistaken for an arterial pulse Such a wave, also, is no direct evidence of congestive failure

The chief venous wave in heart failure appears to be late diastolic Strictly speaking, it may not be a venous pulse wave at all, but merely the steady rise of venous pressure that follows the momentary drop resulting from opening of the tricuspid valve It is seen best in cases of auricular fibrillation when it merges into the "c" wave at the onset of systole and is followed by an abrupt systolic collapse due to descent of the base.

Clinical analysis of the venous pulse may not be easy, but there can be no question that five minutes spent observing the movements of the neck veins may be as informative as auscultation.

Although elevation of the venous pressure at rest, as described in previous paragraphs, usually denotes congestive heart failure, and is a constant sign of such, there are certain circumstances in which it must be interpreted with caution. Slight elevation, for example, may occur when the intra-abdominal tension is high, as in pregnancy, ascites, and intestinal distension; or when the intrathoracic pressure is raised from pleural effusion or pneumothorax. More important, however, are certain conditions (e g anæmia) in which elevation of the venous filling pressure is physiological, as described on page 155 The venous pressure is also raised in hydræmic states from any cause, e g. in acute nephritis and experimental water retention. Finally, it may be very high in chronic constrictive pericarditis and in pericardial effusion.

When the venous pressure is within normal limits at rest, it may yet rise unduly on slight exertion, and may take several minutes to regain its resting level This is a manifestation of limited cardiac reserve The jugular venous pressure normally falls on exertion, because increased ventilation lowers the mean intrathoracic pressure: the true filling pressure tends to rise

Enlargement and tenderness of the liver. Hepatic distension may cause spontaneous pain in the right hypochondrium, especially when it is rapid as in failure from paroxysmal tachycardia Sometimes the pain is related to effort

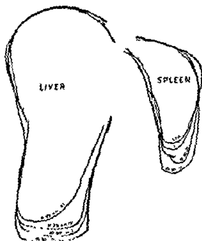


Fig 5 08—Tracings of serial skiagrams of liver and spleen, opacified by means of thorotrast, demonstrating the rapid shrinkage of the liver and spleen which occurs when 1 5 mg of digoxin is administered to a case of congestive failure

Palpation of the liver should be preceded by inspection and percussion Epigastric fullness and dullness to percussion are characteristic of hepatic engorgement, on the other hand, epigastric flattening or concavity, with resonance to percussion, are incompatible with it Percussion of the right hypochondrium during the different phases of respiration often reveals the size of the liver with as much precision as palpation The latter is best carried out with the left hand, the physician standing to the patient's left It may be helpful to place the right hand high up under the right lower ribs, and to exert forward pressure in order to push the liver towards the anterior abdominal wall, if the organ is distended, its edge can be felt with the forefinger of the left hand as it moves downwards during inspiration. Pressure over an engorged liver is painful, and causes immediate swelling of the cervical veins. Hepatic pulsation may be felt in cases of tricuspid incompetence, expansion coinciding with the "c" wave of

the phlebogram. If there is ascites, an enlarged liver may be recognised by "dipping", a repeated sudden pressure of the hand over the region of the liver, when a sensation like that of a patella-tap, or like that of ballotting a fœtus in utero may be appreciated. The liver shrinks as engorgement is relieved (fig 5 08), and this may be demonstrated within half an hour of giving 1 5 mg. of digoxin intravenously (Wood, 1940). After repeated attacks of failure, or after years of persistent distension, cirrhotic changes may occur; but they are unimportant and rarely interfere with hepatic function or with portal drainage.

Fig 5 09—Dependent œdema in congestive heart failure

Although distension and tenderness of the liver are useful signs of right ventricular failure, they are of secondary importance to elevation of the venous pressure, upon which they depend Bad diagnostic errors have been made when heart failure has been diagnosed on the combination of enlargement of the liver and dependent dropsy without a rise in venous pressure. In such cases carcinoma of the stomach or cirrhosis of the liver should receive first consideration

Œdema Of the three classic signs of congestive heart failure, œdema is the least reliable. It may be absent when the venous pressure is high, and gross when it is not so high It is frequently absent in acute cases, especially in children Cardiac œdema is essentially dependent (fig. 5 09), but is occasionally observed in the face, and is not infrequent in the arms It is, of course, accompanied or preceded by oliguria and by a gain in body weight; in fact as much as six litres of fluid may collect in the tissue spaces before pitting œdema is necessarily demonstrable.

Physiologically it is thought that water, electrolytes, and certain other small molecules, such as sugar and urea, leave the blood stream at the arterial end of the capillaries and re-enter at the venous end, the forces at work including the hydrostatic and osmotic pressures within and without the vessels, and the permeability of the vascular endothelium. At the arterial end of the capillary, the hydrostatic pressure exceeds the osmotic; at the venous end it is the other way about. The normal state of fluid balance may be upset in favour of the tissues by raising the hydrostatic

pressure within the capillaries or reducing it without, by reducing the osmotic pressure within the capillaries or raising it without, or by increasing the permeability of the vascular endothelium

Increased hydrostatic pressure at the venous end of the capillaries is the cause of œdema in venous thrombosis, cirrhosis of the liver with tense ascites, and in partial or complete obstruction of the superior vena cava. Low extra-capillary pressure may determine the site of œdema, but does not cause it. Lax tissue occurs naturally in certain situations, e g in the infraorbital region, and may be demonstrated subcutaneously following considerable loss of weight or when the skin has been stretched by previous dropsy. Reduction of capillary osmotic pressure is due mainly to reduction of plasma albumin. Œdema usually develops when the total blood proteins fall below 5 G. per cent Nephrosis, protein starvation, severe chronic anæmia, and gross protein loss in pleural or peritoneal exudates may provide examples of such œdema. The chief effect of increasing the permeability of the capillaries is to allow more albumin to escape into the tissue spaces (a certain amount escapes normally and re-enters the blood stream via the lymphatics), and so to increase the osmotic pressure of the tissue fluid Œdema with a high protein content (3 to 4 G. per cent) results Such œdema may be associated with burns, trench feet, insect bites and allergy (e.g. Quincke's disease). Lymphatic œdema has a similar high protein content

The mechanism of the two most important forms of œdema, cardiac and nephritic, is not yet fully understood In both, as a rule, the protein content of fluid samples is low (less than 1 G per cent), the venous pressure is raised, and the blood volume is increased (Warren and Stead, 1944), but there are exceptions. Thus in chronic anæmia with congestive heart failure the blood volume is much diminished (Sharpey-Schafer, 1944) Increased capillary permeability is excluded by the low protein content of the œdema fluid, moreover, the theory that anoxia might be the cause of such capillary dysfunction is unlikely in that cardiac œdema may be associated with a high cardiac output and normal arterial oxygen saturation, as in arterio-venous aneurysm Elevation of the hydrostatic pressure at the venous end of the capillaries must play a part, but not necessarily a major part In partial superior vena cava obstruction, for example, œdema does not occur until the venous pressure is very much higher than it is in heart failure Reduction of renal blood flow to about 25 per cent of normal in most cases of congestive failure has been demonstrated (Merrill, 1946), and there is a considerable degree of sodium retention, according to Merrill and Cargill (1948), œdema occurs when the filtration rate falls below 70 to 80 ml /litre, tubular reabsorption being almost complete Certainly, artificial sodium retention, contrived by means of a high salt intake and desoxycorticosterone, may cause œdema, and cardiac dropsy is best relieved by means of a low sodium diet or sodium diuresis

OTHER MANIFESTATIONS OF CONGESTIVE HEART FAILURE

It cannot be stressed too strongly that the diagnosis of congestive heart failure rests chiefly upon its peripheral effects and least upon central cardiac findings In addition to the fundamental signs of failure already mentioned, there are a number of other features which may be helpful in doubtful cases, or which should be understood in order that their presence may not cause confusion They include albuminuria and cylinduria, hydrothorax and ascites, cerebral symptoms, cardiac cachexia, venous thrombosis, jaundice, polychromasia, slowing of the erythrocyte sedimentation rate, and certain radiographic appearances

Urinary findings. Oliguria, of course, is associated with œdema The urine, which is rich in colour and of high specific gravity, often contains albumin and hyaline casts, and sometimes a few red cells

Hydrothorax may occur from left or right ventricular failure, and though usually bilateral, tends to be left-sided with the former and right-sided with the latter (Bedford and Lovibond, 1941) It should be remembered that the visceral pleura is drained by a venous plexus which is composed of both bronchial and pulmonary venous radicles In typical instances, the fluid is a transudate with a specific gravity ranging between 1,015 and 1,020, protein is often between two and three per cent, and there may be moderate numbers of leucocytes and red cells Unsuspected pulmonary infarction may further complicate the picture, increasing the specific gravity, the protein content, the leucocyte count and especially the number of red cells, the overlying pleurisy giving rise to an exudate If the fluid is frankly hæmorrhagic, associated pulmonary infarction may be diagnosed with confidence.

Ascites is less common than hydrothorax and usually implies long-standing failure It is a special feature of tricuspid lesions and of chronic constrictive pericarditis

Hydropericardium is rare and is usually of little significance, cardiac compression does not occur, the electrocardiogram is uninfluenced, and there are no symptoms It is only important in that it alters the size and shape of the heart shadow and so may confuse radiographic observations

Cerebral symptoms Difficulty in concentration, impairment of memory, mental confusion, change of character, and manic-depressive, paranoid, or other psychotic states are by no means rare accompaniments of heart failure They are probably attributable to diminished cerebral blood flow, small cerebral thromboses, or anoxæmia; and are encountered particularly in hypertensive or ischæmic heart failure, when cerebral arteriosclerosis may be partly responsible, and in severe anoxic pulmonary heart disease, especially when complicated by broncho-pneumonia

Cardiac cachexia Patients with chronic heart failure usually lose flesh, although loss of weight may be prevented by fluid retention; thus wasting may only be noticed after diuresis; sometimes it is so great as to warrant the

term cachexia. Elevation of the basal metabolic rate, anorexia, impairment of intestinal function, and enforced muscular inactivity may be partly responsible.

Venous thromboses are common in congestive heart failure, especially when the cardiac output is low. They are responsible for the frequency of pulmonary infarction.

Jaundice may occur as a complication of severe heart failure, and may be mainly obstructive (McMichael and Sherlock, 1945) or mainly hæmolytic, the former depending perhaps upon the raised intra-hepatic pressure, the latter upon the destruction of red cells in hæmorrhagic pulmonary infarcts The serum bilirubin is often in the region of 2 mg. per cent.

Immature red cells are a common feature of congestive heart failure, and may be due to stimulation of the bone marrow by anoxia.

The erythrocyte sedimentation rate is often retarded by congestive failure (Wood, 1936) Figures of 50 to 100 in one hour, obtained by the Westergren

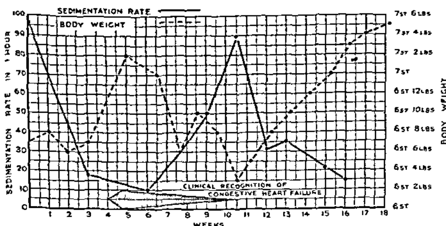


Fig 5.10—Fall in erythrocyte sedimentation rate resulting from the development of congestive failure in a case of active rheumatic carditis

method in cases of rheumatic carditis, myocardial infarction, and syphilitic aortic incompetence, may drop below 10 with the onset of failure, and rise to their former level with recovery (fig. 5.10)

Radiographic appearances. The transverse diameter of the heart is increased by 1 to 2 cm. during failure (figs. 5.11a and b). In making such measurements care must be taken to exclude apparent enlargement due to raising of the diaphragm by an enlarged liver so that the heart takes up a more horizontal position. The superior vena cava throws a denser shadow than usual, and the right auricle is more prominent. The lesser fissure on the right side may be clearly marked owing to pleural congestion, or hydrothorax may be evident.

OTHER CONSIDERATIONS RELEVANT TO HEART FAILURE

Cyanosis Cyanosis is by no means a constant feature of heart failure, and its presence in association with heart disease does not in itself indicate failure It depends upon the presence of at least 5 G per cent of reduced hæmoglobin in the skin capillaries. Thus it cannot occur in severe anæmia, but develops readily if there is polycythæmia The intensity of the hue depends upon the calibre of the skin capillaries: if they are constricted, the colour is paler; if dilated, it is richer. Polycythæmia is the rule in the cyanotic forms of congenital heart disease, and it occurs occasionally in pulmonary heart disease. Capillary dilatation may be seen in the face in many cases of mitral stenosis.

There are three principal causes of cyanosis in heart disease. The first is the right to left shunt seen in congenital heart disease, when venous blood passes directly into the arterial circulation. Central cyanosis of this kind cannot be recognised clinically unless at least one-quarter of the venous blood passes through the defect, assuming a normal hæmoglobin value. With a hæmoglobin of 120 per cent only one-fifth of the cardiac output need be shunted to produce cyanosis, and with a hæmoglobin of 140 per cent, only about one-sixth The second cause is inadequate oxygenation of blood passing through the lungs owing to failure of alveolar function, and is chiefly encountered in acute pulmonary œdema and in pulmonary heart disease secondary to emphysema Clinical recognition of such central cyanosis means that the arterial oxygen saturation is reduced to 80 per cent or less, if the hæmoglobin value is normal. The third cause is the most common and is the sluggish peripheral blood flow in the skin due to compensatory vasoconstriction. It is seen especially in mitral stenosis, primary pulmonary hypertension and massive pulmonary embolism, but it may occur in congestive heart failure from any cause, provided the cardiac output is low

Considerable clinical difficulty may be experienced in attempting to distinguish between central and peripheral cyanosis. If the skin is cold, cyanosis of the face, ears and nail-beds must be assumed to be due to peripheral vasoconstriction; if the skin is warm, and especially if a water-hammer pulse, digital throbbing, and capillary pulsation can be demonstrated, cyanosis is probably central The colour of the conjunctiva, the inside of the lips, or of the palate may be more informative, for cyanosis in these warm situations is always central Direct measurement of the arterial oxygen saturation is recommended in all cases of doubt if accurate information is desired.

The administration of oxygen is most valuable in cases of central cyanosis due to emphysema, but it also increases the arterial oxygen saturation in cyanotic cases of congenital heart disease, and may be used to tide such cases over some critical period

Behaviour of the blood pressure. The blood pressure might be expected to fall in congestive heart failure; but in fact it may rise, fall or remain stationary; in the majority of cases it rises. There are only two conditions in which heart failure is characteristically associated with a sharp drop of blood pressure: acute myocardial infarction and massive pulmonary embolism. In the former the drop is not related to failure (see page 389), in the latter it is more or less proportional to the reduction in cardiac output, and hence to the size of the embolus. Conspicuous lowering of the blood pressure associated with heart failure in other diseases is commonly a terminal event. The vasoconstriction that maintains the blood pressure when the cardiac output falls may depend upon diminished blood flow through the kidney. It may be recognised clinically by cold extremities and peripheral cyanosis.

The heart rate. Whilst some degree of tachycardia, partly due to the Bainbridge reflex (page 110), is usual in heart failure, there are extreme variations, both with normal and abnormal rhythms. If the heart rate is plotted against the cardiac output, a curve may be constructed which is more or less similar in shape to that related to the venous pressure. To some extent it is likely that tachycardia in heart failure represents another compensatory device whereby the cardiac output may be increased. This is well illustrated in chronic constrictive pericarditis when the venous pressure mechanism fails. Clinically, however, tachycardia is an unreliable guide to the presence or degree of failure, as the pulse rate is influenced by so many other factors.

Character of the heart sounds. Current terminology still includes such expressions as weak, faint, or distant heart sounds, and tic-tac or fœtal rhythms which have been supposed to signify failure or threatened failure. With the exceptions of the reduction in the intensity of the heart sounds following coronary thrombosis, pulmonary embolism, and pericardial effusion, weak, faint, or distant heart sounds are commonly due to obesity, emphysema, or well-developed thoracic muscles. It is doubtful whether tic-tac or fœtal rhythm is in any way associated with central heart failure, on the other hand, it is heard in patients suffering from shock, and may be associated with diminution of the blood volume. A weak first heart sound associated with a normal second sound is usually due to a P-R interval around 0.21 to 0.22 second, the mitral cusps then having time to float into apposition before the ventricles contract (Levine, 1948).

PROGNOSIS OF HEART FAILURE

When left ventricular failure develops in the natural course of hypertensive or aortic valve disease, the prognosis is poor, the patient seldom living more than eighteen months after the onset of orthopnœa or paroxysmal cardiac dyspnœa. Few die, however, before clinical signs of chronic systemic congestion become apparent. Moreover, right ventricular failure often brings symptomatic relief, as it reduces pulmonary congestion.

The prognosis may be less unfavourable when acute myocardial infarction is responsible; because if the patient survives the acute phase, he may make a good recovery, and although the average life expectancy is still only 3 to 4 years, the chances of much longer survival are not remote

The outlook is entirely different when left ventricular failure complicates acute nephritis; here complete recovery may be anticipated The ultimate prognosis depends upon the subsequent course of the nephritis Similar remarks apply to other forms of hypertension which are transient or which can be treated successfully

The prognosis of right ventricular failure or congestive heart failure depends very much upon its cause. When associated with diseases that can be cured or improved, such as thyrotoxicosis, the outlook is excellent On the other hand, when it occurs in the natural course of chronic and incurable heart disease, few patients survive more than a year Between these extremes are cases of incurable heart disease in which failure is precipitated by some adverse factor which is either transient or which can be improved or cured. Undue physical work, pregnancy, infection, disturbances of rhythm, obesity, and pulmonary embolism provide examples of such factors

TREATMENT

As the measures used in the treatment of left and right ventricular failure are practically the same they will be considered together. By failure is meant the final stage in which the heart is overloaded

Rest in bed or in a comfortable armchair is essential and should be continued for a minimum period of three weeks. If signs of failure do not disappear within a few days of instituting adequate therapy, the period of rest should be extended to six weeks. The patient should be nursed against a back rest at an angle of about 60 degrees, whether orthopnœic or not, for there is no easier way of lowering the right auricular pressure and so unloading the overburdened heart, if the legs are lowered, so much the better —hence the value of an armchair. *Meals* should be small in quantity and fluids limited to about two pints daily If the *sodium intake* can be limited to 0 5 G daily, however, there is no need to restrict fluids Correct treatment of heart failure usually serves as the best hypnotic; but if insomnia is troublesome at first there should be no hesitation in using morphine.

Venesection deserves a better reputation. It has fallen out of favour because similar results may be obtained by means of certain drugs; but it offers a quick and sure way of lowering the venous pressure and reducing hydræmia, and should not be abandoned Drugs which lower the venous pressure should be used in addition, not as a substitute About 600 to 750 ml. of blood may be withdrawn

Digitalis is beneficial whether there is auricular fibrillation or normal rhythm and whether the pulse rate is fast or slow. It lowers the venous pressure (fig. 5 12), raises the blood pressure (fig. 5 13), slows the heart rate

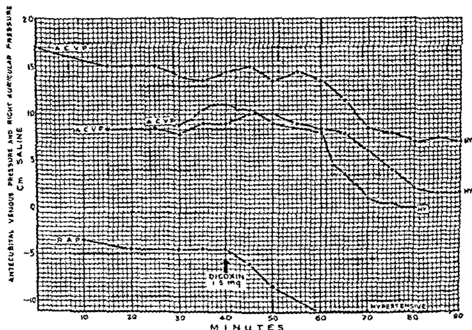


Fig 5 12—Typical effect of digitalis on the venous pressure or right auricular pressure in four cases of congestive heart failure

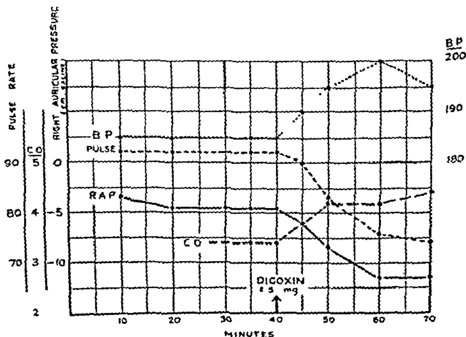
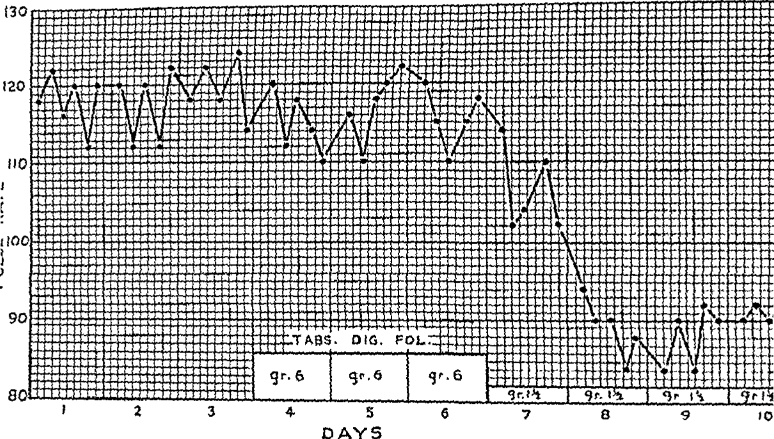


Fig. 5 13—Typical effect of digitalis on the blood pressure, pulse rate, right auricular pressure and cardiac output *in a case of hypertensive heart failure with normal rhythm*



ACUTE RHEUMATIC CARDITIS
CONGESTIVE HEART FAILURE
130
120
110
100
90
80
TABS. DIG. FOL.
gr. 6
gr. 6
gr. 6
gr. 1½
gr. 1½
gr. 1½
gr. 1½
1
2
3
4
5
6
7
8
9
10
DAYS

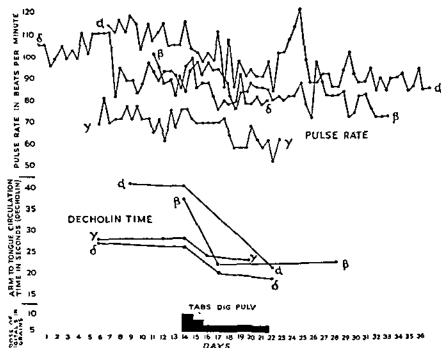


Fig 5 15—The action of digitalis on the arm-to-tongue circulation time and on the pulse rate in four cases of left ventricular failure with normal rhythm.

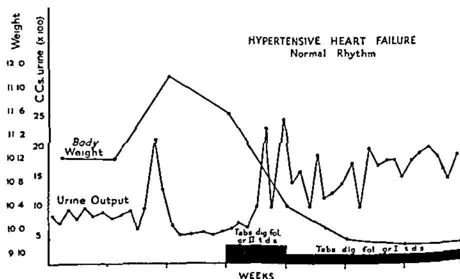
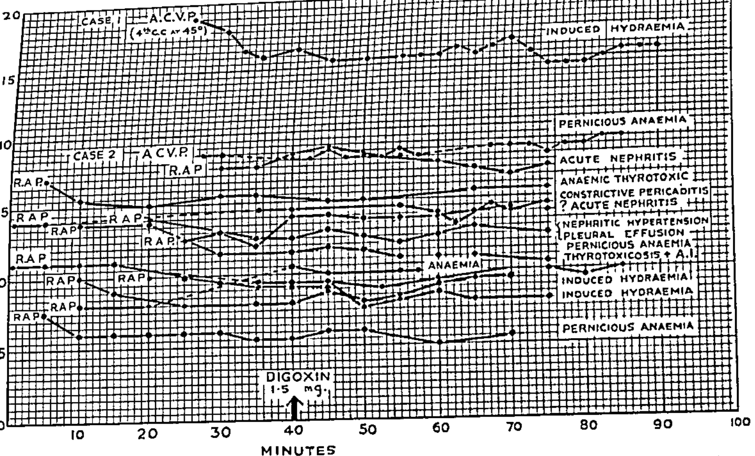


Fig 5 16—Chart showing considerable diuresis resulting from the administration of digitalis to a case of hypertensive heart failure with normal rhythm



…s 17—Chart illustrating the failure of digitalis to lower the right auricular pressure in twelve cases in which it was raised from causes other than congestive failure

(fig. 5 14), relieves hepatic distension (fig. 5.08), increases the vital capacity, shortens the pulmonary circulation time (fig. 5.15), increases the cardiac output (fig. 5 13) and encourages diuresis (fig. 5.16) Its good effects have been recently attributed to a direct venous-pressure-lowering action (McMichael and Sharpey-Schafer, 1944); but this is doubtful, for digitalis does not lower the venous pressure when the latter is elevated from causes other than congestive heart failure (fig. 5.17) (Wood and Paulett, 1949). The original belief that digitalis improves the function of the heart by virtue of its direct action on the myocardium is probably correct In normal controls increase of myocardial tone may make the heart smaller and may reduce its output (Stewart *et al.*, 1938).

For routine purposes the dose of digitalis should be 3 grains (0 2 G.) of the powdered leaf t.d s on the first day, 2 grains (0 13 G) t.d.s. on the second, and 1 grain (65 mg) t.d.s thereafter, until demonstrable improvement or evidence of intoxication occurs, when it may be reduced to 1 grain (65 mg) b i.d. Other methods of administering digitalis are described on pages 144 and 147

Strophanthin may be preferred when a quick action is desired, especially if a cumulative effect is not wanted. A single dose of Ouabain, 1.0 mg. intravenously, may raise the cardiac output in cases of heart failure without affecting the venous pressure (McMichael, 1948), and so presumably acts directly on the heart Like intravenous digoxin it also has a conspicuous pressor effect and slows the pulse rate. Strophanthin is probably the drug of choice in collapsed cases of pulmonary heart failure.

Mercurial diuretics provide the best means of reducing œdema. Moreover, proportional and parallel to the diuresis and to the relief of hydræmia, the venous pressure falls. For this reason they also prevent paroxysmal cardiac dyspnœa (fig. 5.18) They act by encouraging sodium excretion

Preparations on the market include mersalyl, mercurophylline, salyrgan, neptal, and novurit They are all based on the original but far more toxic substance novarsurol, and contain about 40 per cent mercury. Ampoules for injection contain 10 per cent of the drug and 5 per cent of theophylline; oral tablets 0 08 G of the mercurial diuretic and 0 04 G. of theophylline; and suppositories 0 4 G of mersalyl and 0 2 G of theophylline.

Mersalyl should be given in doses of 2 ml. intramuscularly twice weekly, accompanied by 30 grains (2 G) of ammonium chloride orally, once on the preceding evening and repeated three times on the day of injection Mercurial diuretics may be given orally in doses of two tablets t.d s for *two* days, with a rest of three or four days between courses, but they are less effective by this route and may cause considerable gastro-intestinal disturbance. Rectal suppositories, one per week, may also be used, but may provoke severe burning pain.

Toxic reactions are rare, but sudden death has been reported after intravenous injections. Toxic nephrosis, characterised by tubular degeneration and calcification, is encountered occasionally, usually after prolonged

administration. The drug should not be stopped owing to a poor initial response, for the result of the second or third dose, coinciding perhaps with the beneficial effect of rest and digitalis, may exceed expectations. The only contra-indication is acute nephritis.

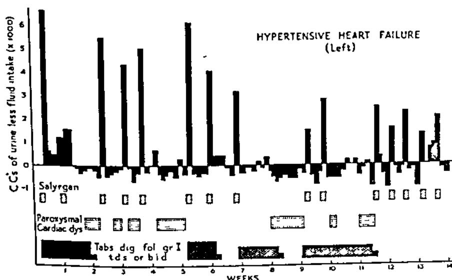


Fig. 5 18—Chart illustrating the beneficial effect of mercurial diuretics in preventing paroxysmal cardiac dypsnœa. Digitalis was less effective

Other diuretics, which may be employed as adjuvants, include the xanthine derivatives, theobromine, theophylline and caffeine; and urea in massive doses, e g. 30 G. t d s. The most powerful of this group is theobromine, which is given in doses of 5 to 10 grains (0 32 to 0 65 G), or combined with sodium salicylate as diuretin in doses of 10 to 20 grains (0.65 to 1.3 G.) The latter being far more soluble is preferable.

A low sodium diet has proved a most effective way of relieving obstinate œdema (Schroeder, 1941) and preventing paroxysmal cardiac dyspnœa. The object is to reduce the sodium intake to the order of 0 5 G daily, so that it is impossible for the tissues to hold much fluid. The blood volume is thus reduced and the venous pressure lowered. The following diet has been constructed from tables giving the composition of numerous foods, compiled by McCance and Widdowson (1946). The first figure after each substance gives the amount of sodium in mgs. per 100 G of foodstuff. The second figure gives the approximate calorific value of the food per mg. of sodium content. For the first 48 hours it is a good plan to give nothing but fruit in any form, fruit juice drinks, sugar, rice and diluted milk. Mercurial diuretics should not, as a rule, be given in conjunction with this diet, the combination causing a too profound degree of sodium and chloride depletion, uræmia, which may prove fatal, may then develop

LOW SODIUM DIET

Cereals

Permitted			*Doubtful*			*Forbidden*		
Arrowroot	4 8	72	Currant bread	164	2	Bread	393	0 7
Barley	0 8	150	Sweet biscuits	216	3	Biscuits	400	0 8
Cornflour	52	7	Rusks	200	2	Cornflakes	1,050	0 3
Flour	2.5	170				Grapenuts	658	0 5
Macaroni	7 9	15				Post-Toasties	810	0 5
Oatmeal	33	11				Ryvita	615	0 5
Rice	2 2	60				Vita-weat	615	0 5
Sago	3 4	100						
Semolina	12	30						
Shredded Wheat	16	22						
Tapioca	4	86						

NOTE

Biscuits Water biscuits and cream crackers contain the most sodium. Oatmeal [illegible]

sugar is recommended.

Milk puddings Milk should be diluted with equal parts of water, margarine must not be used

Flour sauces Make without salt and with equal parts of milk and vegetable water. Use dripping instead of margarine.

Dairy Produce and Fats

Permitted			*Doubtful*			*Forbidden*		
Butter (fresh)	223	3 5	Milk (fresh)	50	1 2	Cheese	600	0 5
Cream cheese (home made)	110	8	Milk (sweet condensed)	143	2	Egg white	192	0 2
Cream	31	13				Margarine	318	0 5
Egg yolk	50	7						
Olive oil	0 1	9,290						
Lard	2	450						
Dripping	5	200						
Suet	25	44						

NOTE

Butter may be kneaded in water to reduce its salt content.

[illegible] ride

Dilute milk 2 : 1.

Use olive oil, dripping, lard or suet in cooking instead of butter or margarine, whenever possible.

Meat, Poultry and Game

Permitted			*Doubtful*			*Forbidden*		
Roast beef	62	6	Chicken	80	2	Bacon	1,200	0 3
Grilled steak	67	5	Duck	195	1 5	Beef (silverside)	1,470	0 2
Stewed steak	38	5 5	Goose	145	2	Brains	150	0 7
Hare (roast or stewed)	45	4 5	Guinea fowl	136	1.5	Ham	1,500	0 3
			Heart	153	1.5			

Permitted			*Doubtful*			*Forbidden*		
Mutton chop (grilled or fried)	90	6	Liver	100	2 5	Kidney	250	0 4
Mutton, leg, etc (roast, boiled or stewed)	68	4	Partridge, Pheasant, Pigeon	100	2	Meat paste	940	0 25
Pork, roast	66	5	Turkey	130	1.5	Smoked pork	1,800	0 15
Pork chops	60	9	Tripe	172	1.5	Sausage	1,000	0 25
Rabbit	32	6	Veal	100	2	Tongue (preserved)	1,870	0 15
Sweetbread	69	3	Venison	86	2			
Tongue (fresh)	79	4						
Topside (beef)	50	4						

NOTE

All salted and preserved meats are forbidden.

[illegible]

N [illegible]

FISH

Steamed fish is [illegible]

[illegible] red mullet, pollan,
fre [illegible]

Preserved, smoked, salted or tinned fish are prohibited (e g tinned salmon is 538/0 25).

Fish not advised include crab, haddock, flat fish, lobster, mussels, oysters (505/0.1), sea trout, whiting and winkles.

Fish paste is prohibited

Fish cakes made without salt and deep fried in olive oil are recommended

FRUIT

Permitted			*Permitted*		
Apples	2	20	Greengages	1 4	34
Apricots	1	30	Oranges	2 9	9
Bananas	1 2	70	Peaches	2 7	13
Blackberries	3 7	8	Pears	2 3	18
Cherries	2 8	16	Pineapple	1 7	29
Currants	2 7	10	Plums	1 7	22
Dates	4 7	27	Quinces	3 2	8
Figs	1 6	26	Raspberries	2 5	10
Gooseberry	1 2	31	Rhubarb	1.5	2 5
Grapes	1 6	40	Strawberries	1 5	17
Grape-fruit	1 4	16			

NOTE

These are average samples of fresh fruits

The only doubtful fruits are melon (19 5/1) and passion fruit (30/1)

Stewed fruit is best, because of its higher calorific value, e g. stewed apples (0 1/170)

Tinned fruits in syrup are also good

Dried fruits are less beneficial, e g. tinned apricots (0 9/62), dried apricots (56/3)

Preserved olives (2,250/0 05) are forbidden

NUTS

Almonds	5.8	100
Brazils	1.5	430
Chestnuts	10 9	16
Hazelnuts	1 4	280
Walnuts	2 7	353

NOTE

These are average examples of fresh nuts.

Obviously salted almonds and peanuts are forbidden.

VEGETABLES

Permitted			*Doubtful*			*Forbidden*		
Artichokes			Artichokes,			Beetroot	64	0 7
(root)	2 6	7.3	globe	6 4	1 1	Carrots	50	0 3
Asparagus	0 9	10	Broad beans	19 6	2	Celery	137	0 07
Butter beans	16.2	6	Cabbage	10	0 6	Radishes	59	0 25
French beans	3.4	2	Cauliflower	11	1	Spinach	123	0 2
Haricot beans	15	6	Cucumber	13	0.7			
Runner beans	3 3	2	Mustard and					
Sprouts	7 7	2	cress	10	0 5			
Leeks	6.4	4	New potatoes	40.5	2			
Lentils	9.4	10	Swedes	14.4	1			
Lettuce	3 1	3 5	Turnips	28	0 5			
Marrow	1 2	6						
Mushrooms,								
fried	11	20						
Onions, boiled	6 6	2						
raw	10 2	2						
fried	20	18						
Parsnips	4 1	14						
dried	12 6	8						
Potatoes, boiled	3.4	25						
roast	8 6	14						
Tomatoes	2.8	5						
Tomatoes, fried	3 3	21						

NOTE

Vegetables must be cooked free from salt. They must not be mashed with margarine or salted butter

Tinned, or otherwise preserved, vegetables, e g. tinned peas (260/0.3), are banned.

SWEETS

Sugar (0.4 984) adds a low sodium high calorific value to most sweets.

Plain chocolate (18 6 29) is better than milk chocolate (93 4/6)

Honey (10.7 26) and jam (15.9 16) are recommended

Golden syrup (270 1), chutney (150/1) and mincemeat (200/0.5) are prohibited

Toffee (115,3 5) and black treacle (96/2.5) should be avoided.

BEVERAGES

Permitted			*Prohibited*		
Coffee	0 3	15	Bournvita	360	1
Lemonade	0.5	100	Bovril	5,580	0 02
Tea	0.4	2	Cocoa	650	0 7
Beer	15	3	Horlicks	690	0 6
Wine			Marmite	6,130	0 01
Spirits			Ovaltine	249	1 5
			Oxo Cubes	10,600	0 02
			Virol	374	1

Condiments

Permitted			*Prohibited*		
Ginger	34	7·5	Curry	450	0·5
Mustard	5	90	Salt	38,500	0
Pepper	7	45			
Vinegar	20	0·2			

Cakes and Pastries

Most of these work out at 150/3, approx.

Doughnuts (60/6), oatmeal biscuits made without salt and with lard instead of margarine, shortbread (86/6), sponge cake (79·4), apple charlotte with suet on top instead of margarine, apple dumpling (39/5), apple pudding (48/5), jelly (8/9·5), pancakes (88/4), and cereal puddings made with diluted milk and no margarine are permitted.

Foods made with soda bicarbonate are not allowed (e g dumpling)

Yorkshire pudding made without salt is permissible.

Currant cake, ginger cake, and Swiss roll should be avoided.

General Rules

No free salt or ordinary salt substitutes, no salt in cooking Sodium free salt substitutes, usually made with potassium, such as neo-seleron, are permitted

No foods made with baking powder.

No medicines containing sodium

No preserved, salted, smoked or tinned foods (except dried and tinned fruit).

Dilute milk with equal parts of water

Use dripping, lard, olive oil or suet instead of butter or margarine, wherever possible.

Supply calories chiefly with selected cereals, cream, fat, fresh meat, potatoes, sugar, sweets, fruit, and nuts

Avoid bread, bread substitutes, certain cereals, margarine, salted butter, cheese, bacon, sausages, meat extracts, shell-fish, fish paste, certain vegetables, and milk beverages

Acupuncture When œdema is gross and fails to respond to the measures previously outlined, it may be necessary to resort to acupuncture A triangular cutting needle is used and about a dozen punctures are made in each leg; the patient is then seated in a chair with his legs in a tub To facilitate drainage, the legs may be swabbed down with warm citrate solution from time to time Due antiseptic precautions must be maintained Fluid may continue to exude for twenty-four to forty-eight hours, and it is not uncommon for the total quantity to be measured in gallons Southey's tubes constitute a cleaner way of removing fluid on the same principle Several large-bore needles are inserted into the subcutaneous tissues of the thighs or calves, and fluid is allowed to drain away through attached rubber tubes into a container

Attacks of paroxysmal cardiac dyspnœa or of acute pulmonary œdema are treated by methods designed to lower the venous filling pressure as quickly as possible and so to reduce the output of the right ventricle The

sitting position will usually have been adopted already by the patient Morphine, ¼ to ⅓ of a grain (16 to 21 mg) intramuscularly, or ⅙ of a grain (11 mg.) intravenously, depresses the excited respiratory reflexes and soothes the patient. Venous tourniquets may be applied round the thighs, to trap blood in the legs, or venesection may be preferred. Theophylline-ethylenediamine (aminophylline), 0.24 to 0.48 G. intravenously, lowers the venous pressure immediately, relieves bronchial spasm, and may have a direct stimulating action on the heart (fig 5.02) Tetraethylammonium bromide, 200 to 300 mg intravenously, is a useful agent for lowering venous pressure, and may relieve attacks quickly (Hayward, 1948)

Digoxin and strophanthin are probably best avoided in view of their pressor actions, indeed, paroxysmal cardiac dyspnœa may occasionally be initiated by intravenous digoxin.

Oxygen is of little value in paroxysmal cardiac dyspnœa, for the arterial oxygen saturation is normal, but may be given with advantage in acute pulmonary œdema Nikethamide is contraindicated, for the aim is to depress respiration, not to stimulate it Adrenaline is dangerous in ischæmic cases because it may provoke angina pectoris, paroxysmal ventricular tachycardia or ventricular fibrillation; but it may be given in small doses subcutaneously to relieve bronchial spasm in hypertensive cases Atropine should be avoided, for it has no therapeutic value and causes unnecessary tachycardia

Cheyne-Stokes breathing may be abolished by carbon dioxide and relieved by oxygen, as already stated, but is best treated by an intravenous injection of 0.24 to 0.48 G of theophylline-ethylenediamine. The effect lasts for six to eight hours and thus ensures a good night's rest According to Marais and McMichael (1937), it is the ethylenediamine radical which is responsible, but other workers (e g Nathanson and Fitzgibbon, 1939) have reported equally good results with theophylline alone or with other theophylline salts These conflicting findings are not necessarily contradictory, for both may be effective, the ethylenediamine radical by direct action on the respiratory centre, theophylline by improving the state of the circulation

Theophylline may also be given by mouth in doses of 0.2 to 0.3 G four-hourly, not only to prevent paroxysmal cardiac dyspnœa and Cheyne-Stokes breathing, but also to lower the venous pressure in congestive heart failure. Larger doses (0.4 to 0.5 G.) may be tried, but usually have to be abandoned owing to dyspepsia.

Dramatic results may follow treatment directed against *the cause of the underlying heart disease* This applies particularly to cases of thyrotoxicosis, anæmia, beri-beri, arterio-venous aneurysm, and anoxic pulmonary heart disease.

If, in spite of all these measures, heart failure continues, an attempt may be made to reduce the oxygen requirement and therefore the work of the heart by means of *thiouracil or total ablation of the thyroid gland* The former

is preferable because the treatment can be abandoned if unsuccessful. Relatively large doses are necessary, usually 0 6 to 0 9 G. daily Propyl thiouracil is advised, for it is less toxic than other preparations. It must be admitted, however, that results are far from satisfactory. Radioactive iodine offers another means of inducing artificial myxoedema (Blumgart *et al.*, 1950)

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CHAPTER VI

SYNCOPE

THERE are many causes of transient loss of consciousness, and a complete list would include the causes of epilepsy, coma, concussion, and asphyxia; but syncope has come to mean transient loss of consciousness of sudden onset due to inadequacy of the cerebral blood flow. As so defined, syncope may be divided into cardiac, vasomotor or vaso-vagal, cerebral and anoxic forms.

CARDIAC SYNCOPE

Cardiac syncope occurs when the heart, through some fault in itself or in its great vessels, fails to maintain an adequate cerebral circulation. These faults are listed for convenience as follows:

1. Cardiac standstill – vagal inhibition.
2. Ventricular asystole – Stokes-Adams fit.
3. Ventricular fibrillation.
4. Ball-valve thrombus or pedunculated myxoma.
5. Aortic stenosis.
6. Paroxysmal rhythm changes with extremely rapid ventricular rates.
7. Massive pulmonary embolism.
8. Cardiac compression from hæmopericardium.

The immediate cause of such syncope is a sudden fall in cardiac output. The practical mechanism whereby the heart fails to fulfil its task varies according to the lesion.

In *cardiac standstill, ventricular asystole, ventricular fibrillation, ball-valve thrombus*, and *pedunculated myxoma*, loss of consciousness is abrupt and without warning. The attack may occur at any time while the patient is walking, standing, sitting, or lying. At first, the patient is grey or white, flaccid, pulseless, and motionless. The heart sounds are inaudible, but respirations may continue. In about 10 to 15 seconds anoxic twitchings begin and may develop into convulsions if the attack lasts long enough. If recovery does not occur within two minutes, death usually results. Cardiac and ventricular asystole usually recover well within that time, commonly within 5 to 20 seconds, but ventricular fibrillation is usually, though not necessarily, fatal. Ball-valve thrombus and pedunculated myxoma are rare. Return to consciousness is abrupt and complete and is followed by a vivid flush, hyper-oxygenated blood being flung into a dilated vascular system (reactive hyperæmia).

Similar attacks of uncertain mechanism may occur in *aortic stenosis*. As

N

a rule, however, syncope in aortic stenosis is vasomotor, the valve lesion acting merely as a predisposing factor.

Heart rates up to 200 per minute in *paroxysmal tachycardia* are usually well tolerated, but syncope may result if the rate is much faster. Speeds of over 300 per minute have been recorded.

Massive pulmonary embolism may cause syncope when more than two-thirds of the circulation is blocked. The onset is sudden, but rarely so abrupt as in the group just mentioned. Moreover, it may be preceded by pain or tightness in the chest The duration of unconsciousness is longer, being usually measured in minutes or even hours. Recovery is at first only partial, extreme faintness persisting During the attack the patient is limp, grey, sweating and breathless The pulse is thready or imperceptible, the heart sounds faint or inaudible, the blood pressure low or unobtainable.

Smaller pulmonary emboli, insufficient seriously to embarrass the circulation, occasionally cause reflex syncope (page 449) Such reactions may be prevented by means of atropine Similar attacks may be encountered in cases of acute myocardial infarction These should not be regarded as examples of cardiac syncope, for the mechanism is vasomotor.

Cardiac compression must be gross to reduce the cardiac output sufficiently to cause loss of consciousness. This condition may be fulfilled by hæmopericardium due to rupture of an aneurysm, dissecting or saccular, or to perforation of the heart from bullet or stab wounds, or spontaneously through a myocardial infarct or ventricular aneurysm.

Syncope associated with aortic incompetence is usually vasomotor in origin, the lesion acting only as a predisposing factor, for the peripheral resistance is already low.

From this brief survey it will be seen that syncope associated with cardiac disorder is of two main types, that in which there is an abrupt and gross fall in cardiac output (true cardiac syncope), and that in which the heart lesion predisposes to vasomotor syncope. A third type is anoxic and is seen in congenital heart disease with right to left shunt.

Further details and treatment of the various forms of cardiac syncope are considered elsewhere.

VASOMOTOR SYNCOPE

Under this heading may be grouped all varieties of syncope in which the cerebral blood flow fails as a result of a sudden fall in blood pressure due to collapse of the peripheral resistance. This includes the common faint.

ETIOLOGY

Vasomotor syncope may be initiated by a critical fall in central venous pressure, by chemical agents that cause sudden profound vasodilatation, or by stimulation of an assortment of receptors which excite a vaso-vagal reaction (Lewis, 1932). Particular causes are listed below:

Causing critical fall in central venous pressure

1. Hæmorrhage
2. Loss of plasma into wounds, burns, crush injuries or gassed lungs
3. Loss of plasma into the skin or tissues as a result of allergy, e.g generalised urticaria and Quincke's œdema
4. Venous tourniquets on the thighs
5. Orthostatic hypotension
6 Other forms of postural hypotension

Chemical agents causing sudden profound vasodilatation

1. Acetylcholine and other cholinergic substances
2. Histamine
3. Tetraethylammonium salts
4 Nitrites

Stimulation of other receptors that excite a vaso-vagal reaction

1 Psychogenic disturbances
2 Carotid sinus compression
3 Extreme pain
4 Myocardial infarction
5 Pulmonary embolism
6 Ménière's syndrome

This list is by no means complete, but it includes all the common causes of vasomotor syncope.

MECHANISM

Syncope from hæmorrhage has been thoroughly investigated in blood-donors. As the blood volume diminishes, the venous pressure falls and the cardiac output is reduced Compensatory vasoconstriction may temporarily maintain the blood pressure The faint, which is associated with a sudden fall in blood pressure and pronounced bradycardia, appears to be due to sudden vasodilatation in muscle (Barcroft *et al*, 1944) This vasodilatation is mediated by vasomotor nerves (Barcroft and Edholm, 1944) Whether this reflex is excited by the fall in venous pressure or otherwise is unknown, but it is clear that diminution in the blood volume is not directly responsible for the faint, for the cardiac output may not alter at the critical moment—the peripheral resistance simply collapses

This sequence of events has also been demonstrated when syncope results from the prolonged application of venous tourniquets to the thighs, and probably occurs in all cases of syncope initiated by a critical fall in central venous pressure (Sharpey-Schafer, 1944) Venous tourniquets on the thighs act as a "bloodless venesection" by trapping blood in the legs. Fainting in soldiers on parade, who may have to stand at attention for long periods, is believed to depend on similar factors The fall in central venous pressure initiating orthostatic syncope following lumbo-dorsal sympathectomy is due

to abolition of veno-motor tone in the lower half of the body. Veno-motor paralysis may also be partly responsible for fainting following the injection of tetraethylammonium salts Spontaneous, toxic, and convalescent orthostatic syncope may also be due to loss of veno-motor tone.

Other forms of postural syncope include fainting in pregnant women when they lie on their backs too long, and fainting in certain subjects on adopting the lordotic position. The fall in central venous pressure is then attributed to compression of the inferior vena cava by a pregnant uterus, or by the liver which is forced against the spine (*Bull*, 1948).

Syncope from chemical agents which cause sudden profound vasodilatation is directly due to collapse of the peripheral resistance The blood pressure falls steeply, but the cardiac output may be raised, and there is usually tachycardia instead of bradycardia. Heat, gross aortic incompetence, and other vasodilatation-states predispose to syncope by lowering the peripheral resistance.

The simple psychogenic faint is initiated by emotional disturbance, or by stimulation of the afferent component of a conditioned reflex; both result in a powerful autonomic discharge The type of emotion usually responsible is a mixture of fear, amazement, and curiosity, as may arise when a nurse sees a thoracic paracentesis for the first time, or when a hypersensitive subject witnesses a street accident. The vasomotor centre appears to be suddenly depressed, and there are associated cholinergic manifestations. the chief result is gross vasodilatation. This is certainly not in the skin, which is pale and cold, but may be in muscle or in the splanchnic bed The peripheral resistance collapses and the blood pressure sinks rapidly. As the cerebral blood flow depends chiefly upon the blood pressure, it becomes inadequate, and consciousness is lost. Spontaneous recovery is inevitable for three reasons first, unconsciousness abolishes the trigger, secondly, liberated acetylcholine, upon which many of the features of the attack may depend, is rapidly destroyed by choline esterase; thirdly, the horizontal position naturally adopted by an unconscious subject increases the cardiac output and is favourable to the cerebral blood flow

Carotid sinus syncope is said to be of four main types which may be reproduced by carotid sinus compression (Weiss and Baker, [illegible] Ferris, Capps

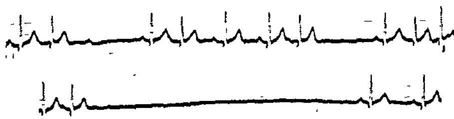


Fig. 6 01—Carotid sinus pressure causing cardiac standstill.

pressure and with marked slowing of the pulse rate If the latter is restored to normal by atropine, consciousness is not regained, if the blood pressure is restored by any means, consciousness returns even though the pulse remains slow. It is the low blood pressure and not the slow pulse rate which is responsible for the syncope. This type corresponds to vaso-vagal syncope Third, carotid sinus pressure may induce syncope associated with a profound fall in blood pressure without slowing of the pulse rate It is doubtful if there is any fundamental difference between these two forms of attack, for not infrequently the first type merges into the second, indeed it has been suggested that initial slowing of the heart occurs in all cases, but ... the low blood pressure

... ing from carotid

Weiss and Baker describe a fourth type of sy... sinus pressure, in which the blood pressure and pulse rate are unchanged, and refer to it as cerebral syncope. This appears to be allied to epilepsy, for no reduction of cerebral blood flow can be demonstrated

Spontaneous carotid sinus syncope may occur in rare instances The organ is hypersensitive and may be excited by sudden pressure of the neck against a tight collar. The condition may be cured by carotid sinus denervation.

Reflex syncope from pain, myocardial infarction, pulmonary embolism, etc., is similar in mechanism to the simple psychogenic faint

CLINICAL FEATURES AND DIFFERENTIAL DIAGNOSIS

The chief clinical problem is the differentiation of vasomotor or vaso-vagal syncope from *epilepsy*. The difficulty lies in obtaining accurate data, for the evidence in the first place is entirely historical, physical examination is almost valueless, as both are disorders of function, not of structure Further, the statements of witnesses, and not only lay witnesses, are notoriously unreliable. In making a diagnosis reliance should be placed on information gained by thorough observation of a spontaneous or induced attack Certain psychiatric or physical features may favour psychoneurosis on the one hand, or epilepsy on the other, but undue weight should not be attached to this

The majority of epileptics have no warning whatsoever If they have an aura, it is odd, and is not related to the autonomic nervous system In sharp contrast, vasomotor syncope is ushered in with numerous signs and symptoms of autonomic disturbance, e g yawning, pallor, sweating, coldness of the skin, a sinking feeling in the pit of the stomach, general muscular weakness, subjective changes of temperature, a feeling as if the blood was ... and nausea, desire to micturate ... faintness, and so forth

... it is instantaneous; at one moment the patient is in full possession of his senses, a split second later he is unconscious. This means that he is unaware of the onset He

may have a fit at night in bed, and know nothing of it. Patients with vasomotor syncope, on the other hand, feel themselves fainting They lose consciousness gradually, and although the onset may be described as quick or sudden, it is never abrupt

The epileptic may have a fit at any time: when he is walking, standing still, sitting, lying, or sleeping, when he is in company or alone, but rarely when his attention is concentrated Psychoneurotics faint when standing up, rarely when sitting, and practically never when lying, they faint in company or when in reach of company, rarely when alone. They are especially liable to attacks in closed spaces, in church, in the cinema, and in circumstances that provoke emotional disturbance.

In epilepsy, muscle tone is usually increased, so that the patient falls rigid like a nine-pin, or if heightened tone is asymmetrical or local, he may fall in a bent or twisted position He is usually discovered lying prone, so that he is apt to drown himself in shallow water, or suffocate in his pillows. In contrast, the muscles are flaccid in vasomotor syncope, so that the patient collapses like a house of cards, his final position being determined by gravity

There are so many varieties of epilepsy that it is difficult to describe all the features which may occur during a fit, but attention should be directed to increased muscle tone, seen especially in the rigid phase of grand mal, to clonic or regular jerking movements of hand, trunk, or limbs, to conjugate deviation of the eyes to one side, to Jacksonian localisation, and to the epileptic march reflecting the anatomy of the motor cortex. Tonic contraction of the jaws and protrusor spasm of the tongue may result in the latter being bitten Incontinence of urine may occur. If the central nervous system can be examined during an attack, the eyes will be found open, the pupils dilated and insensitive to light, the corneal reflexes absent, and the plantar response extensor.

During the rigid phase of grand mal breathing is impossible: the subject becomes increasingly cyanosed, the pulse rate and venous pressure rise, and the heart pounds. During the physical effort associated with clonic convulsions the cardiovascular system behaves as it does with ordinary exertion.

In vasomotor syncope the patient lies flaccid and inert, in a sprawled or crumpled position, and may well be on his back. He is deathly white, and often cold and clammy. The eyes may be open or closed, the position of the upper lid being governed by gravity. The pupils are dilated, and may be insensitive to light, the reflexes and tendon jerks absent or depressed. [illegible] The essential feature [illegible] 50 or 60 mm. Hg; [illegible] is slow, normal or quick. In severe attacks slight twitching may be seen but is unc[illegible]on

The epileptic attack is measured in seconds or minutes, and [illegible] lasts longer than three minutes. Vasomotor syncope is more variable, [illegible]gh usually of short duration may last much longer, even up to

Consciousness is regained as abruptly as it is lost in epilepsy, it is regained gradually in vasomotor syncope.

The epileptic may complain of headache and somnolence after an attack, and of generalised muscle pains and aches after grand mal, but if he does not pass off into a deep sleep, and if he does not suffer from post-epileptic automatism, he recovers completely at once. After vasomotor syncope the patient feels weak and ill; he may complain of headache, nausea, or vomiting, of a continued feeling of faintness or light-headedness, of trembling and shaking, or of cold sweats. He rarely recovers completely for half an hour or so, and usually likes to lie down until he is better

Unfortunately both epilepsy and vasomotor syncope may be complicated by superimposed hysterical reactions, which being more dramatic tend to impress both patient and witnesses to the exclusion of more vital phenomena. This is one reason why historical diagnosis is often so difficult Pure hysterical fits have to be differentiated and this may not always be easy, either by cross-examination of the patient or of a witness Hysterical patients, however, never have an attack when alone, never hurt themselves, and may rememb[illegible]

longer, and on recovery they do not complain of sore tongue, sore muscles, or of having urinated. Despite all these points of difference, if both patient and lay observer are bad witnesses, the distinction between epilepsy, hysteria, and some other form of syncopal attack may be difficult. In such cases electro-encephalography may be helpful, or the patient may be admitted to hospital for observation, and if no spontaneous attacks occur, one may be induced by the water-pitressin test, which depends upon the power of water retention to precipitate an attack of epilepsy.

The patient is put on an ordinary diet and made to drink at least six pints (3.5 litres) of fluid daily When the body weight has increased by at least 3 lb. (1.5 kg.), which usually takes about 48 hours, he is given 0.25 ml of pitressin intramuscularly and 300 ml. of water by mouth, thereafter he is given 0.5 ml of pitressin and 300 ml. of water every two hours, to a total of ten doses if necessary. In epileptic subjects a fit is commonly produced after about the fifth or sixth injection, and allows a correct diagnosis to be made in over 85 per cent of cases

Another simple diagnostic method is the hyperventilation test, which may induce the patient to have one of his attacks

Vasomotor or vaso-vagal syncope initiated by *hæmorrhage* or by any other physical state which lowers the central venous pressure, does not differ clinically from its psychogenic prototype Careful analysis of the circumstances under which the faint occurs may indicate the nature of the causal agent.

Syncope may be produced by the *intravenous injection of acetylcholine,*

mecholin (acetyl-beta-methylcholine) and *doryl* (carbo-amino-acetylcholine). Loss of consciousness is preceded by flushing and a feeling of warmth due to vasodilatation, and by sweating There is commonly abdominal colic, nausea or vomiting, and desire to micturate or defæcate. The blood pressure is low, but the pulse rate accelerates Patients may complain bitterly after regaining consciousness, saying they feel "dreadfully weak", as if they had been ill for months. Ordinary therapeutic doses of mecholin and doryl rarely cause syncope; the dose must be large and given intravenously. Symptoms are relieved at once by 1 to 2 mg. of atropine.

The *intravenous injection of histamine* may also cause syncope due to gross general vasodilatation and collapse of the peripheral resistance Loss of consciousness is preceded by flushing and headache

An interesting and not uncommon form of syncope in elderly subjects may be closely associated with flushing It is encountered in menopausal women and occasionally in men at the climacteric. Both flushes and fainting disappear following the administration of stilbœstrol, 1 to 5 mg. daily

Ménière's syndrome or aural vertigo may occasion difficulty in diagnosis. *Vertigo is usually recognised by its spinning quality, but occasionally there* is no spinning, but merely unsteadiness, imbalance, or sudden attacks in which the subject is thrown violently forwards or backwards. Consciousness is not lost, however, tinnitus is usually associated, and deafness can nearly always be demonstrated.

TREATMENT OF VASOMOTOR SYNCOPE

The causal agent should be identified and counteracted when possible. Orthostatic hypotension may be improved by an abdominal binder, or by bandaging the limbs Provocative postures should be avoided, and patients should be instructed to stand up slowly Stilbœstrol may be tried in menopausal subjects.

Psychogenic syncope calls for reassurance and psychotherapy, for the fear of fainting encourages the faint Fortunately there is no danger attached to vasomotor syncope Patients usually have sufficient warning to ward off attacks by lying down, or by sitting with the head between the knees. Cool fresh air, and bathing the face with cold water are helpful. Brandy, sal volatile, and other stimulants may also be given, or a glass of cold water may be preferred. Half an hour on a couch in quiet, comfortable and sympathetic surroundings consolidates recovery

CEREBRAL SYNCOPE

Cerebral syncope may result from cerebral vascular spasm or transient occlusion. The fault is local.

Hyperventilation syncope is the best example Forced breathing results in carbon dioxide washout with secondary tissue alkalosis. Carbon dioxide ordinarily helps to maintain an adequate degree of cerebral vasodilatation

(Norcross, 1938); its lack causes cerebral vasoconstriction This induces dizziness within a minute in most normal individuals undergoing forced breathing. If hyperventilation is maintained long enough syncope may occur. Spontaneous attacks are seen in hysteria and sometimes in encephalitis lethargica. There is usually associated vasoconstriction in the extremities, with pallor, cyanosis, and tingling of the fingers and toes, and there may be tetany. The blood pressure is maintained or raised owing to vasoconstriction, the latter tending to prevent reduction of cerebral blood flow

Forced breathing may be used as a test in cases of syncope, to discover whether an attack can be reproduced It should be remembered, however, that epilepsy is sometimes excited by hyperventilation, so that the diagnosis depends upon the nature of the induced attack, not upon the simple fact that consciousness is lost. The effects of spontaneous hyperventilation may be quickly abolished by the inhalation of carbon dioxide This may be accomplished by breathing in and out of a paper bag or long rubber tube

Loss of consciousness due to hypertensive encephalopathy or to cerebral vascular lesions with or without associated spasm of cerebral vessels is usually called coma, unless convulsive epilepsy occurs Embolism, however, especially when due to air or fat, may provoke an attack which fulfills the definition of syncope. The onset is abrupt, and recovery may be remarkably quick and complete if the embolism moves on, or if spasm passes off suddenly.

Loss of consciousness occasionally occurs in Ménière's syndrome, but is then probably a vaso-vagal reaction

Bilateral carotid compression, an old ju-jitsu trick, is a most effective way of inducing unconsciousness in an adversary

ANOXIC SYNCOPE

Loss of consciousness resulting from most causes of anoxia is described as asphyxia or coma. Anoxic syncope, however, may occur in congenital heart disease with right to left shunt, when some factor suddenly reduces the amount of blood sent through the lungs: this factor may be something which increases the volume shunted, such as effort or screaming, or it may be something which reduces the venous return to the right auricle, such as an ill-advised venesection, or the sudden adoption of the upright posture by a bed-ridden patient

Syncope in pilots used to be due to anoxia at high altitudes, but this has been overcome by the controlled use of oxygen Nowadays it is chiefly associated with power dives, and is governed by centrifugal forces Syncope in anæmic subjects is usually vasomotor or vaso-vagal, anæmia merely acting as a predisposing factor

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CHAPTER VII

CONGENITAL HEART DISEASE

CONGENITAL anomalies account for 1 to 2 per cent of all cases of organic heart disease (Brown, 1939) They are not hereditary and they are rarely familial. The majority are due to defective development between the fifth and eighth week of fœtal life; some depend upon persistence of certain parts of the fœtal circulation which should become obliterated at birth; a few appear to be caused by infection *in utero* or are associated with German measles in the mother (Swan, 1943). Other congenital abnormalities are found in at least 10 per cent, especially arachnodactyly and mongolism Twins, whether dizygotic or identical, are rarely both affected.

CLASSIFICATION

It has been customary to divide congenital heart disease into acyanotic and cyanotic forms, and to subdivide the latter into types with permanent cyanosis (morbus cœruleus or blue babies) and types with late, terminal or transient cyanosis (cyanose tardive). This has never proved entirely satisfactory, and a new classification is therefore offered It is based on a series of 200 proved clinical cases (Wood, 1950), and takes function into account.

NO SHUNT		
GENERAL	LEFT-SIDED	RIGHT-SIDED
Dextrocardia Idiopathic hypertrophy Von Gierke's disease Heart Block Familial cardiomegaly	Coarctation of the aorta Right-sided aortic arch Complete or incomplete aortic rings Bicuspid aortic valve (or supernumerary cusps) Aortic or subaortic stenosis Left coronary artery arising from pulmonary artery	Idiopathic dilatation of the pulmonary artery Simple pulmonary stenosis Ebstein's disease

WITH SHUNT	
ACYANOTIC LEFT TO RIGHT SHUNT (pulmonary plethora)	CYANOTIC RIGHT TO LEFT SHUNT
Left ventricular enlargement Patent ductus Ventricular septal defect (with or without mild pulmonary stenosis) Perforated aortic sinus into P A or R V (or R A) Aorto-pulmonary septal defect *Right ventricular enlargement* Atrial septal defect Anomalous pulmonary veins joining S V C or R A	DIMINISHED PULMONARY BLOOD FLOW LOW P A PRESSURE 1 *Left ventricular enlargement* Tricuspid atresia 2 *Right ventricular hypertrophy* Fallot's tetralogy Pulmonary atresia (Fallot type) Persistent truncus Pulmonary stenosis with reversed interatrial shunt HIGH P A PRESSURE Eisenmenger's complex Pulmonary hypertension with reversed aorto-pulmonary, interventricular or interatrial shunt PULMONARY PLETHORA Transposition

DEXTROCARDIA

Mirror image dextrocardia is almost invariably associated with complete transposition of the viscera. The heart is functionally and structurally healthy. The electrocardiogram, for obvious reasons, shows reversal of all complexes in lead 1 with leads 2 and 3 interchanged (fig 7 01)

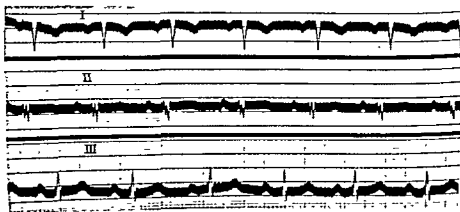


Fig 7 01—Electrocardiogram showing reversal of all complexes in lead 1, while leads 2 and 3 are interchanged

IDIOPATHIC HYPERTROPHY OF THE HEART

A rare condition not often compatible with more than a few years of life is that characterised by general enlargement of the heart progressing to early failure. Some of these cases have proved to be examples of Von Gierke's disease, the enlargement being due to glycogen retention in the muscle fibres of the heart as well as in the liver and other organs There is acetonuria, a low fasting blood sugar, and a flat blood sugar curve following the injection of adrenaline, indicating failure of mobilisation of glycogen Others are due to an anomalous origin of the left coronary artery from the pulmonary artery (Bland, White and Garland, 1933). Yet others prove to be cases of isolated myocarditis (Fiedler's carditis) There remains a group in which the etiology is obscure (Kugel, 1939), gross thickening of the endocardium with embryonic myxomatous tissue richly supplied with elastic fibres (fibroelastosis) is usually found at necropsy, and may be the primary developmental defect (Glynn and Reinhold, 1949)

The heart is grossly enlarged, but remains normal in shape There are no murmurs or other special features. The diagnosis depends on the finding of gross cardiac enlargement for no apparent reason The prognosis is bad and there is no effective treatment.

FAMILIAL CARDIOMEGALY

From time to time, cases of idiopathic cardiac enlargement are encountered in young subjects, for which there is as yet no adequate explanation X-rays show considerable cardiac enlargement, particularly of the left ventricle (fig 7 02). Left bundle branch block is usually found These patients are apt to die suddenly, presumably from ventricular fibrillation, or by degrees from congestive heart failure when still relatively young



Fig 7 02—Unexplained cardiac enlargement in a relatively young man (there was also left bundle branch block)

Some of these cases appear to have a familial basis (Addarii *et al.*, 1946; Evans, 1947) Necropsy reveals little but cardiac enlargement Von Gierke's disease, isolated myo-

carditis, nutritional cardiopathies, and abnormal coronary vessels must be excluded.

COARCTATION OF THE AORTA

The word coarctation comes from the Latin *coarctatus*, meaning pressed together, tightened, or contracted. As applied to the aorta it means a stricture of the arch, usually just below the origin of the left subclavian artery.

Embryology. It will be recalled that there are two primitive aortas, each having a ventral and a dorsal part joined by an arch These three parts are called respectively the ventral aorta, the dorsal aorta, and the first aortic arch. In front, the two ventral aortas fuse to form a single tube from which develops the primitive heart, the truncus arteriosus, and the common ventral aorta. The two dorsal aortas also fuse between the fourth thoracic and fourth lumbar segments, forming a single trunk, the common dorsal or descending aorta. Caudal to the first pair of aortic arches spring five other pairs, the six corresponding to the six branchial arches (fig. 7 03a). In fishes these six vascular arches persist, and supply the gills with blood for oxygenation

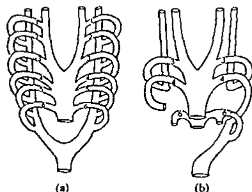


Fig 7 03 (a)—The six primitive aortic arches (b) Subsequent arrangement of the six primitive aortic arches in man (see text).

In man and mammals subsequent development is illustrated in figure 7 03b The first, second, and fifth arches disappear. The third becomes the common carotid artery, the external carotid springing from it anteriorly, the internal linking up via the cranial portion of the dorsal aorta. The fourth arch becomes the proximal part of the subclavian artery on the right side, and the final aortic arch proximal to the junction of the ductus arteriosus on the left. The sixth arches are separated from the aortic system by the aorto-pulmonary septum which divides the truncus into anterior and posterior halves· the anterior half becomes the ascending aorta, the posterior the pulmonary artery. The division of the truncus extends cranially to a point just beyond the anterior ends of the sixth arches, the mouths of which are included in the posterior section and therefore in the pulmonary system. On the right side the sixth arch becomes the right pulmonary artery and loses its connexion with the right dorsal aorta; on the left it becomes the left pulmonary artery and preserves its connexion with the left dorsal aorta in the form of the ductus arteriosus. While these changes are going on, harmonious alterations take place in the ventral and dorsal aortas. In front

the two ventral aortas fuse into a single ascending aorta, as already indicated Behind, the dorsal aortas undergo considerable modification the upper part forms a portion of the internal carotid artery, as previously described; the segment between the third and fourth arches disappears, caudal to the fourth arch the dorsal aorta disappears on the right side, except for that part of it which is incorporated in the right subclavian artery, and forms the posterior part of the aortic arch on the left side The left subclavian artery links up with the left dorsal aorta just below the junction of the sixth arch, i.e. just below the ductus

Many anomalies may result from faulty development of this aortic system Thus, the caudal part of the right dorsal aorta may persist, so that there are two aortic arches; or the caudal part of the left dorsal aorta may disappear in favour of the right, so that the final aortic arch is right-sided The most important, however, is partial obliteration of that part of the left dorsal aorta which lies between the fourth and sixth arches, i.e just above the ductus, or between the sixth arch and the point of fusion of the two dorsal aortas, i.e. just below the ductus This short segment of the aorta is often called the isthmus on account of the frequency with which it is narrowed; but in coarctation or isthmus stenosis narrowing is extreme and often remarkably abrupt. There are two main types, infantile and adult (Bonnet, 1903) In the former (fig. 7 04a) the constriction is above the ductus, which remains patent and carries venous blood to the descending aorta· being incompatible with more than a few years of life it will not be further considered. In the latter (fig. 7.04b) the ductus is closed, or if patent, the constriction is below it, so that it plays no part in compensating for the defect. Aortic atresia with a patent ductus feeding the whole systemic circulation (fig. 7 04c) constitutes a third type (Bramwell, 1947), but such cases all die in infancy Other variants of these three main types have been described by Evans (1933)

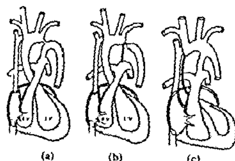


Fig 7 04—Diagrams illustrating the three main types of coarctation of the aorta
(a) Infantile type with patent ductus feeding the descending aorta
(b) Common adult type
(c) Aortic atresia with patent ductus feeding the whole systemic circulation

Hæmodynamics The clinical features of the adult form of coarctation depend upon the mechanical effect of the constriction and upon the development of an extensive collateral circulation Much use is made of the branches of the subclavian artery, e g the superior intercostal, and the internal mammary, with its intercostal, superior epigastric, and musculo-phrenic rami; also of the thoracic and subscapular branches of the

axillary artery. These vessels link up with the intercostal branches of the descending aorta, and with the inferior epigastric branches of the femoral arteries, and so by-pass the constriction. The blood pressure is elevated in vessels arising from the aorta above the isthmus; below it the systolic pressure is reduced and the diastolic raised, the mean pressure often being still above normal. The cause of the hypertension is uncertain. The raised mean pressure in the legs does not support the mechanical hypothesis. Renal ischaemia was blamed by Rytand (1938) on the grounds that hypertension was only produced experimentally when the aorta was constricted above the origin of the renal arteries; but the renal blood flow in clinical cases of coarctation appears to be normal. The truth may not be discovered until the cause of essential hypertension is known.

CLINICAL FEATURES

Coarctation occurred in 8 per cent of the author's series of 200 cases of congenital heart disease. It is said to be 4 to 5 times more common in men than in women, but in the author's series the sex incidence was equal. Hypertension is usually considerable in degree, and may be discovered in childhood. Patients may complain of nose-bleeding, or of undue throbbing. All the usual features of hypertensive heart disease are present, and this is responsible for death from congestive failure in about 40 per cent of cases (Abbott, 1928). Renal failure does not occur because the kidneys are protected by the lesion, but cerebral accidents are not uncommon. Other symptoms include gnawing pains in the shoulder girdle, chest or back; cold feet, and occasionally intermittent claudication.

The major peripheral arteries should be palpated as a routine in all cases of hypertension. In coarctation, femoral pulsation is not only feeble, but delayed, and pulsation in the posterior tibial and dorsal arteries of the feet may be absent. If the blood pressure in the legs can be measured at all by the cuff method, it will be found to be lower than in the arms; but if measured directly by means of a needle in the femoral artery and an electrical manometer, the diastolic pressure is found to be raised, though the systolic is reduced. In other words, the blood pressure in the legs approaches the mean pressure, the amplitude of pulsation being diminished (Brown *et al.*, 1948).

A mitral diastolic murmur is by no means uncommon, even in early childhood, and is usually attributed to coincident rheumatic endocarditis or to established mitral stenosis. There is no evidence as yet that such a murmur is ever functional in coarctation.

The collateral circulation provides the majority of the physical signs, enlarged tortuous vessels giving rise to unusual pulsations and murmurs. Pulsation of some of the intercostal arteries can usually be seen and felt posteriorly, especially if the subject bends forward, and may be associated with similar murmurs. Radiography may reveal notching of the inferior borders of the ribs (fig. 7.05) due to pressure erosion (Railsbach and Dock,

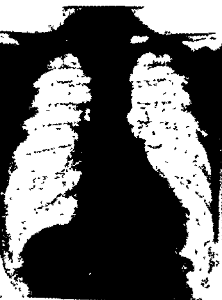


Fig 7·05—Notching of the inferior border of the ribs due to pressure erosion from enlarged intercostal arteries in coarctation of the aorta The "aortic knuckle" is elongated, and is formed by a grossly enlarged left subclavian artery.



Fig 7·06—Visualisation of coarctation of the aorta by means of angiocardiography (*Courtesy of Dr Wallace Brigden*)

1929); this may be seen in children as young as six, but is more obvious in adults.

The constriction itself is difficult to see fluoroscopically, but may be demonstrated clearly by means of angiocardiography (fig 7·06) (Grishman, Steinberg and Sussman, 1941), or retrograde aortography (Broden, Hanson and Karnell, 1948). Hypoplasia of the aortic knuckle, as seen in the ordinary antero-posterior skiagram, is suggestive, especially when associated with left ventricular enlargement. A double aortic knuckle, representing the blind ends of the aorta above and below the constriction, is diagnostic (Bramwell, 1947); it is usual for the upper knuckle to be elongated, being formed by a grossly enlarged left subclavian artery (fig. 7·05)

ASSOCIATED PHENOMENA

Bicuspid aortic valves may be associated (11 per cent in Abbott's series (1928), 42.3 per cent in that of Reifenstein *et al.* (1947)), and may lead to *aortic incompetence* under the stress of the hypertension. *Patent ductus arteriosus*, with the usual clinical features, occurs in 10 per cent of adult coarctations (Bramwell, 1947) Owing to the high pressure gradient between the arch of the aorta and the pulmonary artery, the blood flow through the

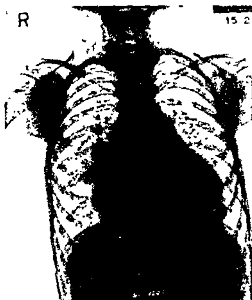


Fig 7 07 (a)—Coarctation of the aorta associated with patent interventricular septum proved at necropsy



Fig 7 07 (b)—Similar case, but without necropsy proof

ductus may be enormous· the pulmonary vessels are thus unusually dense and dilated, the left auricle may resemble that in mitral stenosis, and there is often a mitral diastolic murmur At the same time the systemic collateral circulation may be less in evidence owing to the ready escape of aortic blood into the pulmonary circulation

A very similar picture may be seen when coarctation is associated with patent interventricular septum, the high pressure in the left ventricle causing an unusually large left to right shunt. In a case investigated by the author and subsequently proved at necropsy, the mean pulmonary arterial pressure was 130 cm of saline, whilst that in the right ventricle was 65 to 82 Samples from the pulmonary artery were 86 per cent saturated with oxygen, from the middle of the right ventricle 70 per cent, and from the right auricle and superior vena cava 60 per cent. Clinically, coarctation of the aorta was recognised by the presence of high blood pressure in the carotid and subclavian arteries (160/100 mm Hg in a boy of six) with an immeasurable pressure in the legs, but there was little evidence of a collateral circulation. The pulmonary arteries were grossly engorged radiologically (fig 7.07a), there was a pulmonary diastolic murmur at the

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ndings, the raised oxygen content of the right ventricular sample being ttributed to pulmonary incompetence. At necropsy, coarctation of the orta of the adult type was associated with a large defect of the membranous nterventricular septum. The aortic cusps were normal, the aortic ring dmitted only the little finger, and the ascending aorta was small The lefect in the septum admitted the middle finger, whilst the pulmonary ring admitted both middle and fore-fingers. A very small patent ductus joined the aorta below the isthmus. Although the huge pulmonary artery did not sit astride the septal defect, there could be no doubt that the major portion of the left ventricular contents was expelled into that vessel The mitral diastolic murmur was clearly functional, for there was no sign of mitral stenosis Both ventricles were greatly enlarged, the left retaining its natural dominance. A second example in a man with precisely the same clinical features is illustrated in fig. 7.07b. Cardiac catheterisation excluded atrial septal defect, but did not distinguish patent ductus with pulmonary incompetence from interventricular septal defect The patient died later from congestive heart failure, but there was no necropsy.

Bacterial endarteritis may affect the isthmus, or an associated bicuspid aortic valve. It develops in about 20 per cent of cases *Berry aneurysm* may occur in the region of the circle of Willis, and may result in *subarachnoid hæmorrhage*, especially in those with higher blood pressures Death from subarachnoid hæmorrhage occurred in 9 per cent of 200 cases reported by Maud Abbott (1928) Sometimes there is no aneurysm, but the media or elastic tissue is defective (Glynn, 1940) Similar defects may be found in the aorta and may be responsible for the frequency with which it ruptures (19 per cent of Abbott's series.) *Variations in one or other subclavian artery* occur in about 5 per cent of cases (King, 1937), and may be due to its anomalous (East, 1932) or stenotic (Love and Holms, 1939) origin

PROGNOSIS AND TREATMENT

Although many patients live well into middle life without serious handicap, some even to the eighth decade, the majority succumb between the ages of 20 and 40 to one of the complications mentioned above (Abbott, 1928). The average age of death is 35 (Reifenstein, Levine and Gross, 1947) Surgical repair (Crafoord and Nylin, 1945) should therefore be offered The physiological results of such an operation are usually good the blood pressure falls, symptoms disappear, the heart becomes smaller, and it may be assumed that the risks of intracranial hæmorrhage, aortic rupture and bacterial endocarditis are diminished Crafoord (1948) had successfully repaired 22 cases with only two deaths up to July 1947. The ages of his patients ranged from 11 to 27, but late childhood (age 8 to 12) may be the best time for the operation. Of 52 cases operated on by Gross (1949), there were 7 deaths, 4 failures, and 41 cures, in this series there were eight additional cases that were considered inoperable A mortality rate of 16 per cent amongst 128 surgically treated cases in different centres

was reported by Shapiro (1949). The chief dangers appear to be sudden cardiac asystole when the aorta is clamped, especially if a large left subclavian artery has to be included in the clamp, and tearing out of sutures from a hypoplasic aorta distal to the constriction. Pre-operative preparation and choice of anæsthetic designed to prevent an undue rise of blood pressure when the aorta is clamped, may help to reduce the first risk.

BICUSPID AORTIC VALVE

Bicuspid aortic valve cannot be diagnosed clinically without aortic incompetence or superimposed bacterial infection The former is unusual unless there is hypertension or infection, for a healthy bicuspid valve may be competent against a normal blood pressure Bacterial endocarditis attacks about one-quarter of all cases

AORTIC STENOSIS

Aortic valvular stenosis is rare It differs little from acquired aortic stenosis, but may be accompanied by stunted growth and weak physical development The majority die young.

Subaortic stenosis is perhaps less rare (2 per cent). The lesion, which affects the outflow tract of the left ventricle, is due to defective absorption of the primitive bulbus cordis A perforated membrane lies proximal to the valve The clinical features differ from those of valvular stenosis in that the aortic second sound is clear, the peripheral pulse usually normal, the left ventricle but little enlarged, and the prognosis, apart from the risk of bacterial endocarditis, excellent The diagnosis is not excluded by the deposition of calcium. Some of these cases are mistaken for the Maladie de Roger

Both forms are more common in males than in females.

IDIOPATHIC DILATATION OF THE PULMONARY ARTERY

Cases are seen occasionally with considerable dilatation of the pulmonary artery without obvious cause (Laubry, Routier and de Balsac, 1941) If there is functional pulmonary incompetence, the right ventricle enlarges and partial or complete right bundle branch block may follow, as in atrial septal defect. The pressures in the right side of the heart are normal, and the pulmonary blood flow is not increased. The X-ray appearances differ from those of A.S D. in showing normal pulmonary vessels beyond the two main branches. The prognosis is relatively good.

ATRIAL SEPTAL DEFECT

Embryology. Atrial septal defect refers to a relatively large non-valvular opening in the atrial septum, through which blood may flow either way Embryologically, the atrial septum is formed in the first place by the sickle-shaped septum primum which grows forwards from the dorsal wall of the common auricle, dividing it into two For a time, communication exists between the two auricles in front of the crescentic edge of the growing septum. If development is arrested at this stage, a septal defect results and is situated in the lower anterior part of the septum just below, and usually including, part of the fossa ovalis When growth proceeds normally, this hole is obliterated and a new one, the foramen ovale, appears in the upper and dorsal part of the septum primum; arrest at this stage results in a defect just above the site of the fossa ovalis With further normal development the foramen ovale comes to lie more anteriorly, and is turned into a valve by the growth of the septum secundum on the right side of the septum primum and covering it at all points except over the area known as the fossa ovalis When the septum secundum develops fully and the septum primum degenerates completely, the defect occurs at the site of the fossa ovalis

In *patent foramen ovale* the septa are fully developed, but imperfectly fused. When pressure is applied to the right side of the fossa ovalis, the septa are parted, blood penetrates between them and escapes into the left auricle through the patency in the upper part of the septum primum known as the foramen ovale proper. In fœtal life, the relatively high pressure in the right auricle keeps the valve open, and causes blood to be shunted from right to left in order to avoid the pulmonary circulation At birth the pressure rises in the left auricle and forces the septum primum against the septum secundum, thereby closing the valve In 80 per cent of all individuals fusion then takes place between the two septa and the foramen ovale is permanently closed. In the remaining 20 per cent fusion fails and valvular patency continues Occasionally it causes terminal cyanosis in conditions such as pulmonary heart disease in which the right auricular pressure may come to exceed the left

A cardiac catheter may slip through a patent foramen ovale into the left auricle without difficulty, and may enter the left ventricle (fig 7 08a) or any of the pulmonary veins (fig. 7 08b) The pressures and electrical potentials in these chambers may thus be obtained in favourable cases, including otherwise normal hearts The mean left auricular pressure appears to be 3 to 5 cm of saline above the sternal angle, and is distinctly higher than the right Pulmonary venous samples have always been about 95 per cent saturated with oxygen, whatever the patient's condition (this includes Fallot's tetralogy and other cases of cyanotic congenital heart disease, but not anoxic pulmonary heart disease) Uncomplicated patent foramen ovale is easily distinguished from atrial septal defect because of the absence of any appreciable inter-auricular shunt, as judged by samples from both auricles and their respective venous systems



Fig 7 08 (a)—Catheter in the left ventricle via a patent foramen ovale



Fig 7 08 (b)—Patent foramen ovale proved by cardiac catheterization the catheter has entered a pulmonary vein and has been pulled taut The sharp angle towards the end of the catheter represents the foramen ovale

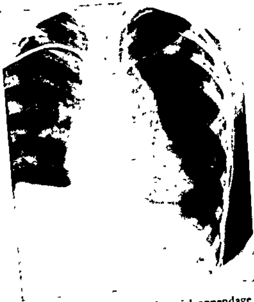


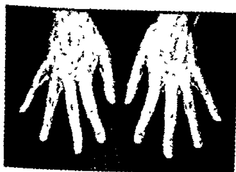
Fig 7 09—Catheter in left atrial appendage



(a) Facies (note bilateral iridectomy)



(b) Showing high arched palate and deformed teeth



(c) Spider fingers

Fig 7 10—A case of arachnodactyly

This patient was 6 ft high and also showed hypotonia, scoliosis, and flat feet

Another interesting anatomical study connected with this work has been the location of the left atrial appendix, which has always been on the left border of the heart between the pulmonary arc and left ventricle (fig 7 09).

Hæmodynamics The defect in the septum is usually 1 to 3 cm. in diameter and carries a considerable shunt from left to right auricle, the pressure being higher on the left Oxygenated blood is thus added to the normal intake of the right ventricle, the stroke output of which is correspondingly increased. The situation is met by right ventricular enlargement and dilatation of the pulmonary artery. Left auricular leakage deprives the left ventricle of its full intake; the left ventricular stroke output is diminished, the left ventricle and aorta hypoplasic, and the pulse small Progressive right ventricular enlargement eventually leads to failure: the pressure in the right auricle then rises, and if it exceeds that in the left, the shunt is reversed and cyanosis develops. Acquired pulmonary hypertension may have a similar effect

Incidence A S D accounted for 17 per cent of the author's unselected series of 200 proved cases of congenital heart disease. It shows a strong preference for females, the sex ratio being 4 : 1 in their favour. Associated mitral stenosis (Lutembacher's syndrome) is remarkably common, especially in females, being present in about 33 per cent of all cases. Other valves may also be affected, and adhesive pericarditis is not infrequent It may be significant that cases of arachnodactyly, which appears to bear some relationship to atrial septal defect, are also prone to develop rheumatic manifestations

Arachnodactyly (fig 7 10) is an hereditary and familial disorder of mesoblastic growth, and is characterised by elongation of the fingers and toes, thin facies, tall lean build, hypotonia (and its consequences), dislocation of the lenses, high arched palate, and pigeon chest. Cardiac abnormalities, especially atrial septal defect, are associated in 40 to 45 per cent of cases

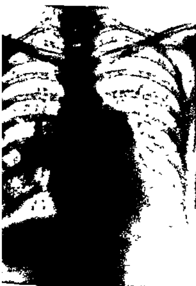
CLINICAL FEATURES

There may be no symptoms until the third or fourth decade, effort tolerance being good, and cyanosis absent; hæmoptysis did not occur in 62 cases analysed recently at the Institute of Cardiology. Between the ages of 25 to 45, however, congestive failure usually develops, and may be associated with the sudden appearance of central cyanosis

Physical signs include a small or normal peripheral pulse, a normal jugular venous pressure without a conspicuous "a" wave; visible or palpable pulsation of the pulmonary artery and outflow tract of the right ventricle, a pulmonary systolic murmur with or without thrill, and a widely split second sound at the base, without accentuation of the second or pulmonary element; not infrequently there is also a basal diastolic murmur due to functional pulmonary incompetence (Graham-Steell murmur). At the apex beat only the tap of mitral valve closure may be discerned, but



Fig 7 11—Skiagram of a case of atrial septal defect, showing gross dilatation of the pulmonary artery and its branches, enlargement of the right auricle, and hypoplasia of the aorta.



(a) Antero-posterior view



(b) First oblique position showing dilatation of the left auricle

Fig. 7 12—Lutembacher's syndrome

occasionally the cardiac impulse is tumultuous, being formed by the distended right ventricle.

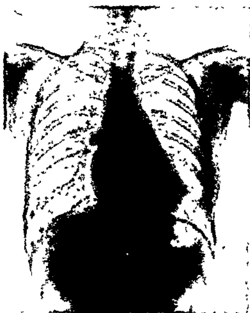


Fig 7 13—Atrial septal defect in a child aged 10

Fluoroscopy in well developed cases (fig. 7.11) reveals gross dilatation and conspicuous pulsation (*hilar dance*) of the pulmonary artery and its branches, considerable enlargement of the right auricle and ventricle, hypoplasia of the aorta and left ventricle, and a flat left auricle In Lutembacher's syndrome (fig 7.12) the left auricle is also enlarged and the right more so In less advanced cases, however, and especially in children, the changes described may be much less noticeable (fig. 7.13)

Electrocardiograms show partial or complete right bundle branch block in 95 per cent of cases (fig. 7.14). Auricular fibrillation occurs in 10 to 20 per cent and is usually due to associated mitral stenosis. The extraordinary frequency of right bundle branch block is interesting in view of the relatively low pressure in the right ventricle, and suggests that dilatation of that chamber is responsible The wide splitting of the second heart sound may well be due, at least in part, to the conduction defect

The diagnosis may be proved by obtaining samples of relatively oxygenated blood from the right auricle, right ventricle, and pulmonary artery, by means of cardiac catheterisation, when samples from the venæ cavæ show ordinary venous blood (Howarth, McMichael and Sharpey-Schafer, 1947) In twenty-five cases investigated by the author (fig. 7 15), samples obtained from the right auricle, right ventricle and pulmonary artery differed little, and ranged between 81 and 90 per cent saturated with oxygen, caval samples being normal (62 to 73 per cent saturated) Samples from the pulmonary veins, left auricle, left ventricle and femoral artery were always between 91 and 96 per cent saturated Mean pressures in the pulmonary artery were lower than expected, all but one ranging between 6 and 18 mm Hg above the sternal angle. The mean left auricular pressure was distinctly raised, and was 10 cm. of saline in one case, presumably because of the increased quantity of blood in the lungs. This suggests that an atrial septal defect initiates a vicious circle, for the shunt apparently increases the pressure gradient between the two auricles—as long as the

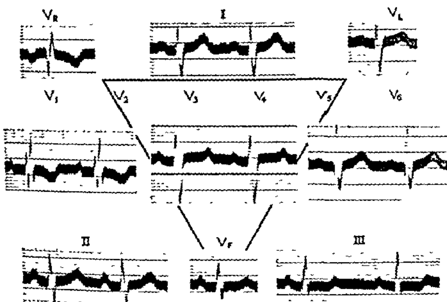


Fig. 7.14 —Electrocardiogram in a case of atrial septal defect showing right bundle branch block

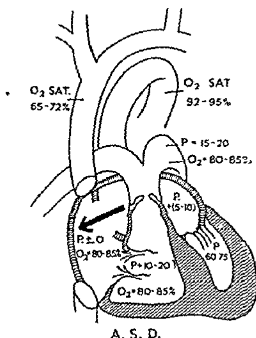


Fig 7.15—Functional studies in atrial septal defect (P=mean pressure in cm of saline above the sternal angle)

right ventricle functions efficiently. Simple calculations reveal that the pulmonary blood flow is usually two to three times the systemic flow, and is of the order of 10 to 15 litres per minute.

Angiograms are less helpful, but an artificial shunt from right to left auricle may be demonstrated sometimes, owing to the sudden rise of right auricular pressure resulting from the large bulk of fluid injected so quickly and forcefully

PROGNOSIS AND TREATMENT

Up to the age of 25 or so there is little disability, but the situation may change radically during the fourth decade, when heart failure (and perhaps permanent cyanosis) may develop. Bacterial endocarditis is extremely rare. The average age of death is 35 to 36, with or without mitral stenosis (McGinn and White, 1933, Roesler, 1934), but several cases over 70 have been recorded

Restriction of effort is advisable, even when there are no symptoms, for the right ventricle must be spared unnecessary work. Should permanent central cyanosis develop, digitalis and mercurial diuretics should be given whether or not there is auricular fibrillation, and whether or not signs of systemic congestion are apparent, for heart failure must be inferred (unless there is tricuspid incompetence).

Surgical repair is in the experimental stage (Murray, 1948).

VENTRICULAR SEPTAL DEFECT

Ventricular septal defect commonly refers to an isolated defect of the membranous part of the interventricular septum due to failure of the aortic septum to fuse with the ventricular septum. Diagnosed clinically for the first time by *Roger* (1879), the lesion has been said to account for 35 to 37 per cent of all cases of congenital heart disease recognised at school age (Perry, 1931, Muir and Brown, 1934). Such high figures probably include instances of subaortic stenosis, simple pulmonary stenosis, mitral incompetence, and innocent parasternal murmur.

In the author's series of 200 proved clinical cases of congenital heart disease, isolated V S D occurred in 12 per cent, and V S.D. with simple pulmonary stenosis in an additional 2 per cent

HÆMODYNAMICS

Functional studies by the author in 16 unselected cases of V.S.D. have shown mean pulmonary artery pressures of 7 to 95 mm. of Hg, the pressure being proportional to the shunt and to the peripheral pulmonary resistance. The latter was increased in three and reduced in four. True pulmonary hypertension from an increased resistance was not due to the size or duration of the shunt, but to some inherent or predetermined factor. Samples from the right auricle have been normal (58 to 76 per cent

saturated with oxygen). At a low level in the right ventricle, just proximal to the pulmonary valve, and in the main trunk of the pulmonary artery saturation figures were similar and were in the region of 81 to 86 per cent saturated.

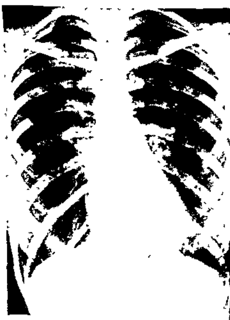


Fig 7 16—Maladie de Roger—X-ray appearances



Fig 7 17—Skiagram of a case of ventricular septal defect with considerable increase of pulmonary blood flow

The degree of shunt from left to right ventricle may be calculated by finding the difference between the blood flow through the pulmonary artery and that through the tricuspid valve

$$\text{Shunt flow} = \text{pulmonary flow} - \text{tricuspid (systemic) flow}$$
$$= \frac{O}{a-p} - \frac{O}{a-v}$$

where O is the oxygen consumption in ml per minute
a is the oxygen content of arterial blood
p is the oxygen content of pulmonary artery blood
v is the oxygen content of mixed venous blood in the right auricle.

In the cases mentioned above the pulmonary blood flow ranged between $1\frac{1}{2}$ and 4 times the systemic flow, and was usually between 11 and 16 L/min.

CLINICAL FEATURES

The majority have no symptoms, but severe cases may develop congestive failure in childhood or adolescence. There is no cyanosis.

The pulse is small or normal, and the jugular venous pressure normal or slightly raised. The cardiac impulse is left ventricular in type and usually hyperdynamic, the right ventricular outflow tract is inclined to be lifting, and pulmonary artery pulsation may be visible or palpable. A systolic thrill and murmur are nearly always present, and are commonly maximal in the third and fourth intercostal spaces at the left sternal border, but may be higher A functional mitral diastolic murmur due to a torrential mitral blood flow is heard in at least half the cases and in nearly all severe cases. The second heart sound at the pulmonary area is normally split, the second or pulmonary element being commonly accentuated. A functional pulmonary diastolic murmur occurs in about a quarter of the more severe cases

The electrocardiogram is normal in mild cases, but shows prominent Q waves and tall R waves (with or without T or U wave changes) in left ventricular surface leads, and conspicuous secondary R waves without much widening of QRS in leads V1 or V2, in the majority, appearances suggesting both left and right ventricular enlargement

X-rays reveal pulmonary plethora, a varying degree of dilatation of the pulmonary artery and left ventricular enlargement in all but the mildest cases (figs 7.16 and 7 17), appearances that are indistinguishable from those of patent ductus.

It will be appreciated that these clinical features are not those described by Roger It is suggested, therefore, that the term Maladie de Roger should apply only to mild cases which show nothing abnormal apart from the Roger thrill and murmur, i e to about one quarter, or at most one third, of all cases of V S D

In differential diagnosis the maladie de Roger must be distinguished from innocent parasternal murmur, subaortic stenosis, mild pulmonary stenosis and organic mitral incompetence V.S.D. in its wider sense is more likely to be confused with atrial septal defect or patent ductus arteriosus. If due regard is paid to the quality of the cardiac impulse, to the nature of the pulse, and to the electrocardiogram, in addition to the site and character of the murmur and to the X-ray appearances, a correct clinical diagnosis is usually possible.

Cases that develop true pulmonary hypertension are in danger of reversing the shunt should this occur the situation would be clinically indistinguishable from the Eisenmenger complex (page 244).

There have been some interesting cases in which characteristic signs of a ventricular septal defect discovered in childhood have disappeared with advancing years. Whilst it is difficult to prove that these were not examples of innocent left parasternal murmur, it has been suggested that spontaneous

obliteration of small defects may sometimes occur (Parkes Weber, 1918)

The prognosis would be good in mild cases were it not for the 25 per cent risk of bacterial endocarditis. When this occurs, emboli are confined to the pulmonary circulation (unless *infection spreads to the aortic valve*), vegetations occurring round the defect on the right ventricular side, and on the opposite wall of the right ventricle where the shunted blood stream impinges Patients with pulmonary plethora are in a different category, and may die from congestive heart failure in adolescence (Baldwin, Moore and Noble, 1946).

No reparative treatment is yet generally available, but Murray (1948) has made the attempt. Mild cases should be encouraged to lead normal unrestricted lives, but severe cases need care and should limit their physical activities. Dental treatment, sore throat and other pyogenic infections should be covered by a short course of penicillin to prevent endocarditis

PATENT DUCTUS ARTERIOSUS

Incidence. Whilst failure of the ductus arteriosus to close within a few months of birth is often associated with other congenital anomalies, it is relatively common alone, especially in females, the sex incidence being 2 1 in their favour (Benn, 1947). It was the main or sole lesion in 9 2 per cent of 1,000 cases of congenital heart disease collected by Abbott, and accounted for 14 5 per cent of the author's series

Hæmodynamics The ductus connects the left branch of the pulmonary artery with the arch of the aorta just opposite the origin of the left subclavian artery As the aortic pressure is higher, the blood flow is from aorta to pulmonary artery, and its degree depends not only upon the size of the ductus but also upon the pressure gradient between these two vessels There is thus an aortic leak, the equivalent of an arteriovenous shunt, and a raised pressure and blood flow in the pulmonary artery The volume of blood entering the left auricle is greater than normal and the left ventricular stroke and minute output are increased. The total blood volume is also increased (Cassels and Morse, 1947)

CLINICAL FEATURES

There are usually no symptoms when the lesion is first discovered

Owing to the large stroke-volume and aortic leak the pulse is abrupt and collapsing, the pulse pressure raised, and the diastolic blood pressure rather low, especially after exertion, when it may drop grossly (Bohn, 1938) The cardiac impulse is forceful, displaced to the left, and suggests left ventricular enlargement The classical "machinery" murmur (Gibson, 1900), usually accompanied by a thrill, begins just after the first sound, waxes towards the end of systole, and wanes in late diastole It is more or less localised to the second left interchondral space Occasionally, especially in infants and young children, the murmur is confined to systole, very rarely it is entirely diastolic, possibly due to pulmonary incompetence If not

heard at rest it may be encouraged by pressor agents, exercise, amyl nitrite or Muller's experiment. It may be reduced or abolished by raising the pulmonary arterial pressure or lowering the aortic, e.g. by Valsalva's experiment, breath-holding, making the patient breathe 10 per cent oxygen, or by hypotensive agents The increased pressure within the pulmonary artery causes accentuation of the pulmonary element of the second sound. In severe cases, a functional mitral diastolic murmur is usually heard, due to dilatation and rapid filling of the left ventricle—hence the not uncommon mistake of confusing patent ductus with aortic incompetence and mitral stenosis.

Fluoroscopy (figs 7 18 and 7.19) reveals abrupt dilatation and conspicuous pulsation of the pulmonary artery, pulmonary plethora, enlargement of the left ventricle and fullness of the left auricle (Donovan, Neuhauser and Sosman, 1943) In contrast to atrial septal defect and mitral stenosis, but like hyperkinetic pulmonary heart disease, the aortic knuckle is normal or prominent A local bulge in the region of the aortic isthmus can be demonstrated by means of angiocardiography in a limited number of cases, and is thought to represent the widened mouth of the ductus, or possibly a traction aneurysm of the aorta (Steinberg, Grishman and Sussman, 1943) With suitable technique, angiocardiograms may also show the pulmonary artery filling twice, first from the right ventricle, then from the aorta Retrograde aortography offers an alternative means of obtaining good angiograms.



Fig 7 18—Skiagram of a case of patent ductus showing enlargement of the left ventricle, but little dilatation of the pulmonary artery

The electrocardiogram is usually normal; but when the ductus is large there may be evidence of left ventricular hypertrophy, (fig. 7.20) Extreme cases may show the classical electrocardiographic changes of gross left ventricular enlargement (fig. 7 21).

The diagnosis may be proved in doubtful cases by means of cardiac catheterisation (fig 7 22). Samples of blood from the superior vena cava, right auricle and right ventricle are normal (about 70 per cent saturated), whereas samples from the pulmonary artery are usually 80 to 85 per cent saturated. Slight admixture of arterial blood in right ventricular samples



Fig 7 19—Skiagram of a more advanced case of patent ductus, showing considerable left ventricular enlargement and engorgement of the pulmonary vessels in addition to dilatation of the pulmonary artery

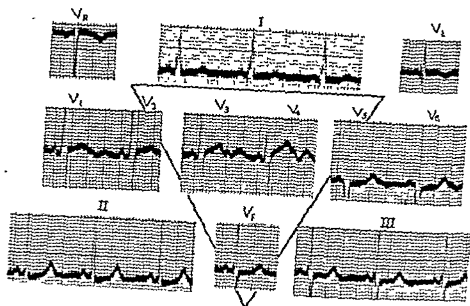


Fig 7 20—Electrocardiogram in a case of patent ductus showing *left* ventricular enlargement There is a strong QR pattern with inverted U waves in lead V_5.

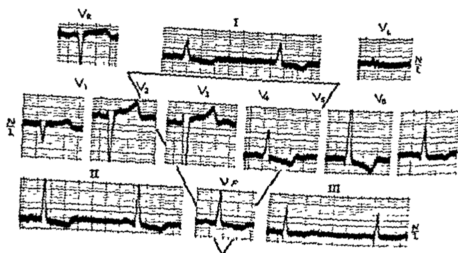


Fig 7 21—Gross left ventricular preponderance in a case of patent ductus

should be left alone Bacterial endocarditis should be cured by means of penicillin, if possible, before submitting the patient to operation.

The chief diagnostic errors that have resulted in fruitless thoracotomy have been due to mistaking some other source of a continuous murmur for a ductus: a normal venous hum at the base of the neck in a child, arterio-venous aneurysm of the lung, and perforation of the sinus of Valsalva into the pulmonary artery or right ventricle may be responsible for such a murmur. In cyanosed cases a machinery murmur may be due to direct communications between bronchial and pulmonary arteries.

Although pulmonary engorgement diminishes and the heart decreases in size after successful ligation in most instances (fig. 7 23), irreversible changes are encountered occasionally, and for this reason severe cases should not be left too long

PULMONARY STENOSIS

Pathogenesis. Subvalvular stenosis is thought to be due to arrested evolution of the bulbus cordis, most of which should become incorporated in the right ventricle (Keith, 1909) The obstruction is in the outflow tract or conus of the right ventricle. There are two kinds· in one the primitive bulbus forms a separate chamber between the pulmonary artery and right ventricle and communicates with the latter by a small lower bulbar orifice which is the cause of the stenosis; in the other the conus is diffusely constricted, leaving a narrow passage between the right ventricle and pulmonary valve Valvular stenosis is proving more common than previously thought: the valve is then represented by a conical membrane with a small circular hole in the centre, or the cusps may be fused in a manner resembling inflammatory stenosis

CLINICAL FEATURES

Simple acyanotic pulmonary stenosis with closed septa accounted for 10 per cent of the author's series of 200 cases of congenital heart disease The stenosis is usually valvular, and cases are acyanotic until reduction of cardiac output and compensatory peripheral vasoconstriction lead to a sluggish surface blood flow In other words, cyanosis, when it occurs, is peripheral, not central, the arterial oxygen saturation being normal The chief symptoms are progressive breathlessness on exertion and ultimately those of congestive failure In severe cases angina pectoris and frightening syncopal attacks may occur.

In relatively severe cases the physical signs include a conspicuous "a" wave in the jugular pulse (which may be transmitted to the liver), a high pulmonary systolic thrill and murmur, a single second heart sound, and a right ventricular form of cardiac impulse. The thrill and murmur may be lower in cases of infundibular stenosis (10 per cent) In mild cases the cardiac impulse may be normal and the second heart sound clearly split



Fig 7.24—Skiagram of a case of simple pulmonary stenosis showing dilatation of the pulmonary artery and hypoplasia of the *aorta*

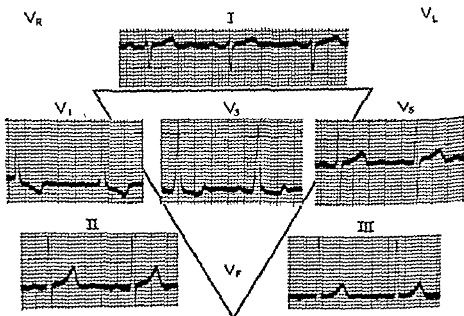


Fig. 7.25—Electrocardiogram of a case of simple pulmonary stenosis showing *right* ventricular enlargement.

Skiagrams usually show dilatation of the main trunk of the pulmonary artery but not of its branches, hypoplasia of the aorta and left ventricle, and enlargement of the right (fig. 7.24). The electrocardiogram may exhibit the usual pattern associated with marked right ventricular dominance (fig 7.25), and tall sharp P waves similar to those of chronic pulmonary heart disease; but in mild cases it is normal.

A high right ventricular pressure and low or normal pulmonary artery pressure may be demonstrated by means of cardiac catheterisation

Diagnosis When the chief features of a case conform to the above description, the diagnosis of simple pulmonary stenosis is probable; but subaortic stenosis, atrial septal defect and ventricular septal defect must be carefully excluded. A common source of confusion is encountered in children with poorly developed chests, who present a loud pulmonary systolic murmur and vibration The mechanism may depend upon the proximity of the anterior chest wall to the pulmonary artery in thin, flat-chested individuals. Confusion is greater when skiagrams reveal prominence of the pulmonary artery, and electrocardiograms right axis deviation The final proof may rest with cardiac catheterisation.

Investigation of apparently typical cases by this method may also provide proof of associated V S D or A.S.D. when not suspected. Five examples (2.5 per cent) have been encountered by the author, high right ventricular pressures and relatively low pulmonary artery pressures confirming the diagnosis of pulmonary stenosis, and partial admixture of arterial blood into samples obtained from appropriate chambers proving the existence of a left to right shunt Reversal of this shunt is possible in severe cases Patent foramen ovale without interauricular shunt was also discovered during cardiac catheterisation in one of the author's cases This was a girl of 14 with a mean pulmonary artery pressure of 8 mm Hg and a right ventricular pressure of 32 The pressure in the right auricle was 3; in the left 4 mm Hg If the stenosis becomes a little more severe the left auricular pressure is likely to fall and the right to rise: she will then develop an interauricular shunt and become cyanosed

Prognosis Bacterial endocarditis and pulmonary tuberculosis are important risks Patients who survive these two evils may reach middle age before dying from right ventricular failure, but the majority succumb when still young The average age of death in Abbott's post-mortem series was 20 6 years, the upper limit being 57

TREATMENT

Pulmonary valvulotomy (Brock, 1948) should be considered in severe cases, but carries too great a risk, at present, for the majority Life may be prolonged by a sedentary occupation and by limitation of effort Complications may be prevented by guarding against dental sepsis and throat infection, by prophylactic chemotherapy when indicated, and by annual radiological examination of the chest in order to detect early pulmonary tuberculosis at a stage when it may be successfully treated

PULMONARY STENOSIS WITH REVERSED INTERAURICULAR OR INTERVENTRICULAR SHUNT

(incidence 2.5 per cent)

Relatively mild or moderately severe cases of pulmonary stenosis may have a patent foramen ovale that is functionally closed. A catheter may be *passed through the valve flap into the left auricle and samples prove the* absence of a shunt, as described on page 242.

As life advances, however, pulmonary stenosis may become more severe the pressure in the right side of the heart then rises, and the foramen ovale may suddenly begin to function and permit the passage of blood from right to left auricle. Such cases illustrate very well what is really meant by late central cyanosis or cyanose tardive. Patients with simple pulmonary stenosis and A.S.D. or V.S.D. may behave similarly.

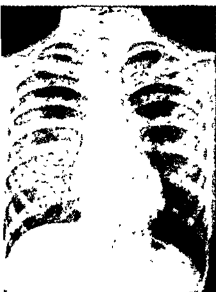
The change is apt to occur in the teens or early twenties and is accompanied by the development of breathlessness, and sometimes by syncope on effort Cyanosis is notably variable and patients may turn almost black on exertion Simple pulmonary stenosis with reversed interventricular shunt resembles Fallot's tetralogy, but the aorta is not over-riding

In the most severe cases of pulmonary stenosis the pressure in the right auricle exceeds that in the left from birth, and the foramen ovale cannot close. Under these circumstances patients have permanent central cyanosis and proportionate functional incapacity from birth

The clinical findings in cyanosed cases differ little in other respects from severe cases without cyanosis; but skiagrams may show diminished vascular markings in the lung fields (fig. 7 26a) and the heart is usually larger (fig 7.26b) Despite the theoretical consideration that the left ventricle is the better filled chamber, the cardiac impulse retains its right ventricular quality and the electrocardiogram usually shows extreme right ventricular dominance (fig 7.27)

It will now be appreciated that there are three main functional types of simple pulmonary stenosis—acyanotic without shunt (with or without patent foramen ovale), acyanotic with direct left to right shunt (through an atrial or ventricular septal defect), and cyanotic with reversed shunt (usually interatrial via a patent foramen ovale, but occasionally through an atrial or ventricular septal defect). The stenosis is valvular in 90 per cent and subvalvular in 10 per cent, and occasionally there is a separate infundibular chamber. Cyanosed cases are always severe; acyanotic cases may be mild or severe

Cardiac catheterisation revealed low mean pressures in the pulmonary artery (below 8 mm. Hg) and high mean pressures in the right ventricle (over 30 mm. Hg) in severe cases, whether cyanosed or otherwise; and normal mean pulmonary artery pressures (over 8 mm. Hg) and moderately raised right ventricular pressures (under 30 mm. Hg) in the mild cases.



(a) Showing dilatation of the pulmonary arc and pulmonary ischæmia



(b) Showing considerable cardiac enlargement and pulmonary ischæmia

Fig. 7 26—Pulmonary valvular stenosis with reversed interatrial shunt.

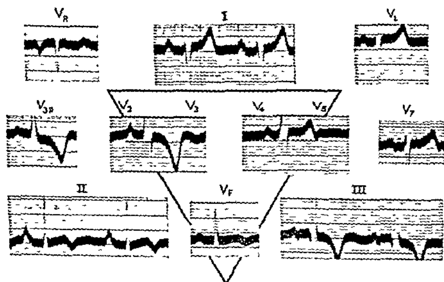


Fig 7 27—Strong right ventricular dominance due to pulmonary valvular stenosis with reversed interauricular shunt

Typical findings in a severe cyanosed case are illustrated in fig 7.28 Samples from the pulmonary veins were fully saturated with oxygen, but left auricular samples were only about 70 per cent saturated, showing gross admixture of venous blood via the defect. Samples from the left ventricle and femoral artery were similar and thus excluded Fallot's tetralogy.

The position of the catheter when being withdrawn through a large foramen ovale or atrial septal defect is characteristic, its transverse segment

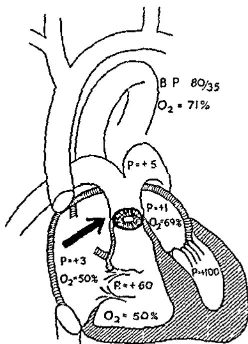


Fig 7 28—Findings on cardiac catheterisation in a typical case of pulmonary valvular stenosis with reversed interatrial shunt. (Pressures in cm. of saline).



Fig 7 29—Catheter penetrating the left auricle through an atrial septal defect, showing the high position of the latter (case of pulmonary stenosis plus A.S D)

riding remarkably high in the centre of the heart shadow (fig 7.29) The position of the catheter when it enters the various pulmonary veins is also characteristic (fig 7 30), and is usually coiled on the right side. It may be added that owing to the direction of the interatrial shunt the catheter tends to pass through the defect very easily, perhaps more readily than through the tricuspid valve.

Angiocardiography confirms the interatrial shunt by showing immediate filling of the left heart. Owing to simultaneous opacification of both ventricles, it is very difficult to obtain an unobstructed view of the outflow tract of the right ventricle, and it is usually impossible to confirm the site of the stenosis by this means.



(a) Right upper



(b) Right lower



(c) Left upper

Fig 7 30—Catheter lying in the pulmonary veins

TREATMENT

Pulmonary valvulotomy is advised in all cyanotic cases with valvular stenosis, the outlook being otherwise grave. By raising the pressure in the pulmonary artery and left auricle and lowering it in the right side of the heart, valvulotomy closes or reverses the interatrial shunt (depending on the anatomy of the defect in the atrial septum). If the obstruction to the right ventricle has been sufficiently relieved that chamber should be able to cope with its increased stroke-volume; if not, it is liable to fail.

The Blalock-Taussig operation is not advised, because the extra work falling on the unrelieved right ventricle consequent upon closure of the foramen ovale or reversal of the interatrial shunt usually causes early death from heart failure. Such cases appear to have shown, however, that increasing the pulmonary artery flow does raise the left auricular pressure.

FALLOT'S TETRALOGY

The combination of pulmonary stenosis, patent interventricular septum, "riding" aorta, and enlargement of the right ventricle is known as Fallot's tetralogy (Fallot, 1888), and accounts for 75 per cent of cases of congenital heart disease with clubbing of the fingers, polycythæmia, and permanent central cyanosis The stenosis is usually subvalvular and is due to great narrowing and distortion of the right ventricular outflow tract The pulmonary artery, instead of being dilated as in simple pulmonary stenosis, is remarkably small and may resemble a vein. By "riding" aorta is meant displacement of the root of the aorta to the right (dextroposed aorta), so that it sits astride the septum, and appears to arise as much from the right as from the left ventricle The association of these three malformations is no accident, but depends upon the same embryological defect, the fault lying with arrested evolution of the bulbus cordis with incomplete torsion A right-sided aortic arch is found in about 25 per cent of cases (Blalock, 1948)

Hæmodynamics Aortic blood is arterio-venous, being composed of the full output of the left ventricle and part of that from the right. The right ventricle has a double burden, for it must work against a constricted outflow tract and compete with the left ventricle against the systemic blood pressure *The situation is met by great hypertrophy of the right ventricle*, the fourth constant finding in the tetralogy. The deficient pulmonary circulation is occasionally improved by extensive development of the bronchial vascular system. Polycythæmia helps to compensate for anoxæmia. Occasionally the defect is partly corrected by patency of the ductus; but a continuous murmur on either side of the chest usually signifies pulmonary atresia with an extensive broncho-pulmonary anastomosis

CLINICAL FEATURES

Fallot's tetralogy, including three cases of pulmonary atresia, occurred in 18 per cent of the author's series This figure is probably influenced by slight weighting in favour of anomalies amenable to surgical repair

Cyanosis, polycythæmia, and clubbing of the fingers may be absent in infants, but develop in early childhood, and tend to be progressive Growth may be stunted and mental development retarded in severe cases The chief symptom is breathlessness, and to obtain maximum comfort children often adopt a characteristic squatting posture (Taussig, 1947) Improvement sometimes occurs owing to the development of a bronchial collateral circulation



(a) Antero-posterior view



(b) Second oblique position

Fig 7 31—Skiagram of a case of Fallot's tetralogy showing the cœur en sabot

The pulse is apt to be small, the jugular venous pressure normal, and giant "a" waves unusual The cardiac impulse is tapping, and no pulmonary artery pulsation can be detected A systolic murmur is usually heard, being high in one third, and in the Roger area in the remainder



Fig 7 32—Right-sided aortic arch in a case of Fallot's tetralogy

A thrill is felt in half the

Fig 7 33—Angiocardiogram of a case of Fallot's tetralogy showing simultaneous opacification of the aorta and pulmonary artery, i e a right-left shunt The stenosis appears to be subvalvular Both pulmonary and both subclavian arteries can be seen

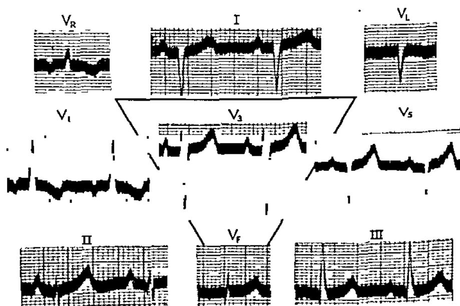


Fig 7 34—Electrocardiogram of a case of Fallot's tetralogy showing marked right ventricular dominance



(a) Main trunk





(b) Right pulmonary artery (1st oblique view) (c) Left pulmonary artery (2nd oblique view)

Fig 7 35—Catheterisation of the pulmonary artery in a case of Fallot's tetralogy

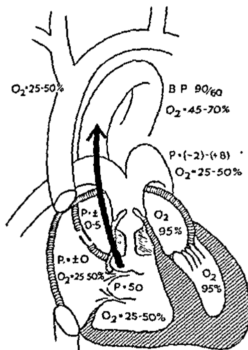


Fig 7 36—Average catheter findings in Fallot's tetralogy (Pressures in cm of saline)



Fig. 7 37—Penetration of the foramen ovale and pulmonary veins in a case of Fallot's tetralogy.

cases, and may be high or low. The second sound at the base is single, never split, owing to the absence of the pulmonary element, and may be quite loud.

The skiagram is usually pathognomonic, and is characterised by conspicuously clear lung fields due to diminution of the pulmonary vascular markings, by a notable gap between the aortic knuckle and ventricles due to hypoplasia of the pulmonary artery, and by a tip-tilted cardiac apex (fig 7 31) This is the "cœur en sabot", for it resembles the shape of a peasant's *wooden shoe with turned-up* toe. The effect is produced by considerable hypertrophy of the right ventricle, with displacement of the interventricular septum to the left, so that the left ventricle appears as a small cap above the right ventricular apex. Occasionally the lung fields present a reticular appear-



Fig. 7 38—Site of abrupt pressure change in pulmonary valvular stenosis



Fig 7 39—Pulmonary subvalvular stenosis the tip of the catheter is still in a low-pressure zone





(a) Catheter lying in right pulmonary artery, which can be seen clearly.





(b) Left pulmonary artery [not obvious in (a)] outlined after injecting 5 ml of 70 per cent diodone through the catheter

Fig 7 40—Demonstration of the anatomy of the pulmonary arteries in a case of Fallot's tetralogy

ance, representing development of the bronchial circulation. In the left anterior oblique view the heart shadow may be globular, owing to the increased curvature of the right auricle and ventricle. If the aorta is right-sided, the knuckle may be seen above the right auricle (fig. 7.32) and the barium-filled œsophagus is deflected to the patient's left. The shunt may be demonstrated by means of angiocardiography (Grishman, Steinberg and Sussman, 1941), which shows immediate filling of the aorta and great vessels, and undersized pulmonary arteries (fig. 7.33). The antero-posterior view is advised in order to reveal the anatomy of both subclavian arteries—a point of considerable interest to the surgeon

The electrocardiogram shows extreme clockwise rotation or right ventricular dominance (fig. 7 34), and often the tall sharp P wave of right auricular hypertrophy.

Cardiac catheterisation may be helpful in doubtful cases. The patient should receive 50 to 100 mg. of heparin at the start of the procedure in order to minimise the risk of paradoxical thrombo-embolism, and great care must be taken not to introduce air into the system. Rigid asepsis should also be maintained, and adequate doses of penicillin should be given for forty-eight hours to prevent the possibility of subsequent cerebral abscess

In twenty-one cases studied by the author the mean right ventricular pressure ranged between [illegible] 40. The pulmonary artery was e[illegible] pressures falling sharply to less th[illegible] he range being −1 to +7, and the average +3 5 (fig. 7 36). The right auricular pressure was usually close to zero (−1 to +3). A patent foramen ovale was penetrated in three cases (fig. 7 37) the left auricular pressure was higher than the right on each occasion, and samples from the pulmonary veins and left auricle were about 95 per cent saturated with oxygen, showing that there was no right to left interatrial shunt. The similarity of samples from the venæ cavæ, right auricle, right ventricle and pulmonary artery proved the absence of left to right shunt: all these samples were grossly unsaturated (94–212 ml. per L) Samples from the femoral artery were mostly between 45 and 75 per cent saturated with oxygen.

Catheterisation not only proved the diagnosis and degree of *Fallot's* tetralogy in these cases, but showed whether the stenosis was valvular or subvalvular. In valvular stenosis the change from right ventricular to pulmonary artery pressure and pulsation was abrupt, and occurred when the tip of the catheter passed beyond the level of the left atrial appendage, a horizontal line through which has been found to mark the level of the pulmonary valve in controls (fig. 7.38). In subvalvular stenosis the pressure changed at a lower level, and sometimes less abruptly (fig. 7.39).

Cyanosis, polycythæmia, clubbing, and a low arterial oxygen saturation prove the existence of a veno-arterial shunt. The size of the shunt may be calculated by subtracting the pulmonary blood flow from the tricuspid (systemic) blood flow.

Owing to the scanty pulmonary blood flow, small quantities of 70 per cent diodone (5 to 10 ml.) introduced directly into the pulmonary artery via the catheter opacify the pulmonary vessels very well (fig. 7 40)

The demonstration of an arm-to-tongue circulation-time of less than six seconds (McGuire and Goldman, 1937) is practically valueless, the test being unreliable, unnecessary, and apt to thrombose precious veins.

The conspicuous rise in arterial oxygen saturation that occurs when a patient with Fallot's tetralogy is placed in an oxygen tent has been confirmed by most workers, and has not yet been satisfactorily explained. The thesis that the function of the pulmonary epithelium is impaired cannot be maintained in view of the fully oxygenated samples of blood obtained from the pulmonary veins in cases with patent foramen ovale

Prognosis. Uncomplicated relatively mild cases may reach middle life, but the majority die young. According to Campbell (1948), only one patient in ten with congenital cyanotic heart disease reaches the age of 24, and only one in five reaches the age of 12. Bacterial endocarditis, pulmonary tuberculosis, pyogenic respiratory infection, and cerebral abscess from paradoxical embolism (Robbins, 1945), are the most serious complications, but the majority appear to die from asphyxia Congestive failure is rare

TREATMENT

Prophylactic therapy should be directed against infection and overwork Pyogenic pulmonary infection may require treatment in an oxygen tent Venesection is contraindicated, for dangerous anoxæmia and syncope may result.

As a result of Taussig's observation that infants with Fallot's tetralogy deteriorated when the ductus arteriosus closed, and that cases complicated by persistent patent ductus fared better than those without, she and Blalock devised the anastomotic operation which has proved so successful (Blalock and Taussig, 1945, Blalock, 1946) One or other subclavian artery is anastomosed to the homolateral branch of the pulmonary artery Better alignment is obtained, as a rule, with the right subclavian; but the left has a longer intrathoracic course and is therefore easier to bring down If results are poor, a second anastomosis may be carried out later on the opposite side.

Another method of achieving the same object is to make a direct anastomosis between the aortic arch and the left pulmonary artery (Potts *et al*, 1946, 1948)

Selection of cases for operation should be based on the following criteria

1 The diagnosis should be proved
2 The patient should have sufficient disability (apart from cosmetic discontent)
3 The arterial oxygen saturation should be less than 75 per cent at rest
4 The mean pulmonary artery pressure should be close to zero, certainly less than 10 cm. of saline

5. Both pulmonary arteries should have been demonstrated.
6. Both subclavaian arteries should have been demonstrated.
7. The anatomy of the aortic arch should have been demonstrated.

Angiocardiography and cardiac catheterisation supply most of the required information.

According to Bing (1947), the oxygen uptake per litre of ventilation does not increase during effort in Fallot's tetralogy or in other cyanosed cases of congenital heart disease that would be improved by the Taussig-Blalock operation, and the test is being used to aid the selection of cases suitable for surgery.

The best age at which to operate is between 3 and 10 years The physiological results of technically successful anastomosis are good: cyanosis and [illegible]

(Taussig, 1948); a loud machinery murmur and coarse thrill may be detected on the homolateral side immediately after the operation in nearly all cases, and are permanent. The risks of pulmonary tuberculosis and bronchopneumonia are likely to be diminished, but the incidence of bacterial endocarditis should not be altered.

Blalock's total mortality rate for this operation is 17 per cent, but this includes infants (mortality rate 25 per cent), cases of tricuspid atresia and other anomalies. His mortality rate for selected cases of Fallot's tetralogy is not more than 10 per cent.

If the stenosis is valvular, an alternative operation is pulmonary valvulotomy (Brock, 1948). The results in successful cases are satisfactory but the risks appear to be heavier. Further technical experience, however, may reduce the mortality rate. Moreover, certain types of subvalvular stenosis may also be amenable to direct attack.

EISENMENGER'S COMPLEX

Relatively rare cases occur in which "riding aorta", patent interventricular septum and right ventricular enlargement are associated with a normal right ventricular conus, normal pulmonary valve, and dilated pulmonary artery (Eisenmenger, 1897). The riding aorta allows venous blood to escape into the systemic circulation, so that slight to moderate central cyanosis occurs. The prognosis is much better than in Fallot's tetralogy, the majority of cases attaining middle life.

The physical signs include a systolic thrill and murmur maximum at the third left intercostal space near the sternal border, palpable pulsation over the pulmonary artery, accentuation of the second or pulmonary element of a normally split second sound at the base, and occasionally a pulmonary or aortic diastolic murmur.

Right ventricular enlargement and dilatation of the pulmonary artery

may be demonstrated by means of electrocardiography and X-rays (fig 7.41) The arterial oxygen saturation is reduced, usually to 70 to 80 per cent, right ventricular and pulmonary artery pressures are raised, right ventricular and pulmonary artery samples are similar to samples from the right auricle and superior vena cava, and angiocardiography (fig. 7 42) shows simultaneous opacification of the aorta and pulmonary artery



Fig 7 41—Eisenmenger's complex

(By courtesy of Dr Maurice Campbell)



Fig 7 42—Angiocardiogram of a case of Eisenmenger's complex showing simultaneous opacification of the aorta and dilated pulmonary artery

(Sussman and Grishman, 1947) In two cases investigated by the author and proved with the aid of angiocardiography the shunt was only from right to left, samples from the pulmonary artery being the same as those from the right side of the heart The arterial oxygen saturation was 72 per cent in one case and 71 per cent in the other, and the pulmonary blood flow was considerably reduced in both. Unlike Fallot's tetralogy, however, the mean pressure in the pulmonary artery was high

In differential diagnosis it is well to remember that the majority of cases that appear at first to be examples of the Eisenmenger complex turn out otherwise. The following should be considered

1 *Atrial septal defect with late reversal of the shunt* Wide splitting of the second heart sound, right bundle branch, left auricular blood samples containing a proportion of venous blood, and angiocardiograms showing immediate filling of the left auricle distinguish it

2. *Pulmonary hypertension with late shunting through a patent foramen*

ovale. This is distinguished by catheter samples from the left auricle and by angiocardiograms as described for (1) above.

3. *Idiopathic pulmonary hypertension with late reduction in arterial oxygen saturation.* There is usually no pulmonary systolic murmur; pulmonary venous blood samples are improperly saturated, and are similar to samples from the left auricle, left ventricle and femoral artery; angiocardiograms show no shunt.

4. *Anoxic pulmonary heart disease.* This does not cause confusion when there is obvious advanced emphysema, but it may give rise to difficulty when the degree of emphysema seems insufficient to cause cyanosis. The absence of an intracardiac shunt must then be demonstrated.

5. *Transposition of the great vessels with patent septa.* Cyanosis is usually earlier in onset. Samples of blood from the pulmonary artery contain more oxygen than samples from the aorta or peripheral arteries, and samples from the right auricle are more saturated than those from the venæ cavæ. Angiocardiograms may be inconclusive. Skiagrams show pulmonary plethora.

6. *Ventricular septal defect or patent ductus with reversal of the shunt due to pulmonary hypertension.* Such cases are clinically indistinguishable from the Eisenmenger complex.

TREATMENT

Blalock's operation is contraindicated, because an artificial ductus cannot function well when the pulmonary blood pressure is raised; nor is the arterial oxygen saturation low enough to warrant it.

OTHER ANOMALIES CAUSING PERMANENT CYANOSIS

The remaining malformations listed in the classification on page 203 are rarely compatible with more than a few months of life unless associated with other anomalies that have a favourable influence on hæmodynamics.

Transposition of the great vessels, the pulmonary artery arising from the left ventricle and the aorta from the right, results in two independent circulations Life depends principally upon an atrial septal defect whereby oxygenated blood from the left auricle passes into the right side of the heart and so into the aorta, and upon a patent interventricular septum through which venous blood in the right ventricle may be pumped into the lungs

The chief presenting features are central cyanosis associated with a split second heart sound, dilatation of the pulmonary artery and engorgement of the pulmonary vascular shadows (fig. 7.43). The electrocardiogram reveals gross right ventricular dominance or right bundle branch block. Cardiac catheterisation shows that samples from the pulmonary artery (entered from the right ventricle via the ventricular septal defect: fig. 7.44) contain more oxygen than samples from the aorta (also entered from the right ventricle: fig. 7.45) or femoral artery, a state of affairs that can occur in no other

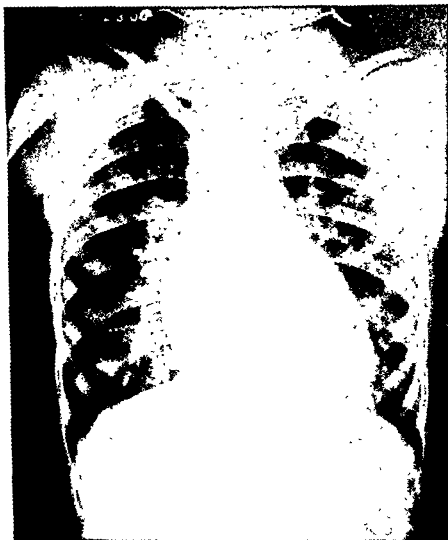


Fig 7 43—Skiagram of a case of transposition of the great vessels associated with atria and ventricular septal defects



Fig 7.44—Skiagram of a case of transposition of the great vessels showing penetration of the pulmonary artery from the right ventricle via the ventricular septal defect



Fig 7 45—Skiagram of a case of transposition of the great vessels showing a catheter penetrating the aorta directly from the right ventricle

condition. Aortic samples are similar to those from the right ventricle and auricle, and contain considerably more oxygen than samples from the superior vena cava by virtue of the interatrial shunt. In a case investigated by the author, samples from the aorta and right heart were 82 per cent saturated, from the superior vena cava 60 per cent, and from the pulmonary artery 89 per cent. The right ventricular systolic pressure equals the aortic pressure. The pulmonary blood flow is greatly increased (9 L /min. in the case cited), the aortic decreased (3 L /min.). Angiocardiography shows simultaneous filling of the aorta and pulmonary artery from the right ventricle. A second case investigated showed no A.S.D., but greater pulmonary plethora. The catheter was again manipulated into both aorta and pulmonary artery

Persistent truncus arteriosus is due to failure of development of the aorto-pulmonary septum, so that a single large vessel arises from both ventricles Blood is carried to the lungs either by pulmonary arteries arising from the common trunk, or by way of the bronchial arteries. Cyanosis is minimal when the pulmonary arteries are present, extreme when the pulmonary blood flow depends on the bronchial arteries. Radiologically, the aortic knuckle and vascular pedicle are unduly prominent and there is a conspicuous bay between the knuckle and the left border of the heart. Both ventricles are grossly enlarged

A harsh systolic murmur and thrill are usually present at the base, and the second heart sound is loud and single. The electrocardiogram shows right ventricular dominance or right bundle branch block. Angiocardiography helps to establish the diagnosis, especially when the pulmonary arteries are absent, but appearances closely resemble pulmonary atresia.

A Blalock-Taussig operation may benefit those cases in which the blood flow to the lungs is reduced, that is those cases with severe cyanosis in which the bronchial arteries supply the lungs.

Tricuspid atresia with a functionless right ventricle and atrial septal defect is characterised by intense permanent cyanosis due to right to left interatrial shunt, by gross left ventricular enlargement and by electrocardiographic evidence of considerable left ventricular preponderance. The blood flow to the lungs is greatly reduced and depends upon a patent interventricular septum, patent ductus, or upon the bronchial collaterals. The latter may link up directly with the larger pulmonary arteries and cause a widespread bilateral machinery murmur. The diagnosis may be confirmed by means of angiocardiography (fig 7.46) and cardiac catheterisation, and the condition may be greatly improved by the Blalock-Taussig operation.



(a)



(b)



(c)



(d)

Fig 7 46 —Angiocardiogram in case of tricuspid atresia (a) Showing dye passing directl into left auricle (1 second) (b) Showing early filling of the left ventricle and aorta (2 seconds note bronchial collaterals in right upper zone (c) Second oblique position the left side the heart and the aorta are filled in 2 seconds (d) At 3 seconds a small left pulmonary arte is becoming visible

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CHAPTER VIII

RHEUMATIC FEVER AND ACTIVE RHEUMATIC CARDITIS

RHEUMATIC fever is a particular form of polyarthritis following streptococcal infection: its hall-marks are pancarditis, chorea, subcutaneous nodules and erythema marginatum. It may be acute, subacute or chronic.

INCIDENCE

According to the 1927 report of the Child Life Committee of the Medical Research Council, "Social Conditions and Acute Rheumatism", 10 to 15 per cent of all children at 12 years of age in England are affected by rheumatism. Of 22,800 children under 15 years of age card-indexed by the London County Council, 2.6 per cent had had rheumatic fever (Bach *et al*, 1939) The crude annual death-rate from rheumatic fever declined from 67 per million persons in 1901 to 22 per million in 1937 (Glover, 1939) During 1937, according to Glover, rheumatic fever accounted for 2 3 per cent of all deaths in children between the ages of 5 and 9 years

The disease is rare in infancy and in old age, and is most common in childhood and adolescence, attacking the poor rather than the rich, and having an incidence climatically and geographically parallel to streptococcal tonsillitis (Coburn, 1931) The peak incidence is in children between the ages of 8 and 12, particularly during the months of October-November and of January-February. Apart from arachnodactyly there is no evidence that a particular physical type is predisposed to rheumatic fever (Hill and Allan, 1929), but hereditary predisposition is now accepted (Wilson, 1940)

THE NATURE OF THE RHEUMATIC STATE

There is no evidence, as yet, that rheumatic fever is caused directly by any infective agent Cultures from blood, joint fluid, pericardial or pleural effusions, and from affected tissues are bacteriologically sterile, and filtrates from similar samples are incapable of transmitting the disease when inoculated into animal or man There is still, perhaps, a remote possibility that a virus is responsible, but the known facts are against it.

On the other hand, the evidence that rheumatic fever is intimately related to streptococcal infection is beyond dispute The relationship was first propounded by Poynton and Paine in 1900 They isloated a diplococcus from blood and other cultures and produced polyarthritis and carditis by injecting it into animals; but the lesions were shown later to be infective, not rheumatic. However, they confirmed the observation of Haig-Brown

range between 3 and 30 per cent in clinical studies, and between 25 and 66 per cent in post-mortem studies (Rogen, 1947). These figures are probably too high. The subject is well reviewed by Bywaters (1950).

PATHOLOGY

In a *fulminating* attack which ends fatally within two or three weeks, tissue microscopy reveals only non-specific lesions consisting of œdema, fragmentation of collagen, leucocytic infiltration, hyperæmia and capillary hæmorrhage (Coburn, 1933). Similar lesions may occur in most acute infections, toxæmias and allergic states, and represent the Arthus phenomenon (Werner, 1938). Many tissues are so affected, particularly the synovial membranes of the larger joints, the pericardium, myocardium, and endocardium, the pleura and lung Petechiæ may be seen clinically in the skin (purpura rheumatica) or in the ocular fundi, and at autopsy they are often most obvious in the pericardium and pleura. Inflammatory œdema of soft tissues may be seen clinically, independent of arthritis. Effusion into the large joints, and sometimes into the pericardial or pleural cavities, is characteristic and is the best example of the exudative type of lesion.

The specific rheumatic lesion, however, is proliferative, and occurs rather later; it is characterised by the Aschoff node (Aschoff, 1904) This is a small collection of large, often multinucleated, reticulo-endothelial cells, mixed with lymphocytes and plasma cells, surrounding a necrotic collagenous centre, there is also fibroblastic proliferation Whilst it is in no sense perivascular, it lies in close relationship to a vessel. This lesion is particularly well seen in the myocardium Another example of the proliferative lesion is the subcutaneous nodule, which may be regarded as an aggregation of Aschoff nodes with fibroblastic tissue predominating Macroscopic nodules may be seen occasionally on the surface of the heart (fig 8 01)

Occasionally, vascular lesions are found in the viscera which show all the [illegible]

calcified.

Rheumatic inflammation of the heart valves is a true valvulitis, the baneful agent entering the valve through the minute vessels which supply it (Shaw, 1929) There has been considerable disagreement concerning the vascularity of normal and diseased heart valves Langer (1887) first demonstrated the dependence of valvular blood vessels upon the presence of muscle he showed that vessels and muscle fibres reached the free edge of the valve in the fœtus and new-born child, but soon regressed; also that diseased valves were frequently vascularised whereas normal adult valves were not. Gross and Kugel (1921, 1925-26, 1927-28, 1931), who studied the coronary circulation in detail by means of radiography after injecting a barium sulphate gel, confirmed Langer's observations. They also found

that in the fœtus the pulmonary valve was the one best provided with muscle and blood vessels, whereas in children it was the aortic cusp of the mitral valve. The fact that endocarditis *in utero* usually affected the pulmonary valve, whereas in children it usually affected the mitral valve, thus appeared to be understood. The decreasing incidence of valvulitis as age advanced was similarly explained. More recent work based on the injection of Indian ink instead of barium gel, however, has thrown doubt on these



Fig 8 01—Macroscopic nodules on the surface of the heart.

conclusions. Wearn *et al.* (1936), for instance, found capillaries in the valves of 84 per cent of seventy-four normal hearts, and were unable to correlate the relative incidence of endocarditis of a given valve with the frequency with which it contained blood vessels. Thus the mitral valve was vascularised in 66 per cent, the tricuspid in 64 per cent, the pulmonary in 28 per cent and the aortic in 16 per cent.

In the acute stage of rheumatic inflammation the valve is œdematous, and soon shows signs of damage just proximal to its free edge where the cusps come into apposition, i e. at the site of maximum natural trauma. Small thrombi form on the valve at this site giving rise to a ridge, or to a row of small pink nodules As the inflammation subsides, secondary sclerosis follows and results in thickening and shortening of the chordæ tendineæ, in thickening and distortion of the cusps, and especially in fibrosis and constriction of the mitral ring at the base of the valve. According to Carey Coombs (1924), mitral stenosis usually takes 2 to 8 years to develop. If the

mitral ring is spared, and the brunt of the attack falls upon the chordæ tendineæ and the periphery of the cusps, mitral incompetence may occur without stenosis, and may become extreme if ring dilatation follows owing to dilatation of the left ventricle. Rheumatic aortic valvulitis results in thickening and distortion of the cusps, with fusion of the commissures, secondary calcification and stenosis are common. Tricuspid valvulitis with late stenosis or incompetence is by no means rare

CLINICAL FEATURES

In childhood, the heart often bears the brunt of the attack, and indeed the joints may escape entirely. Once the heart has been involved, however, carditis or valvulitis should be assumed in all subsequent attacks, the increased vascularity of a valve which has been subjected to rheumatic inflammation may partly explain this tendency to recurrence If the first attack occurs over the age of 21, carditis is unlikely, and becomes progressively rare with advancing years, although it may still occur even in old age. Polyarthritis, on the other hand, becomes increasingly common

The diagnosis of rheumatic carditis is based on three major issues upon signs of some inflammatory process, upon evidence that this process is rheumatic, and upon proof of cardiac involvement

SIGNS OF SOME INFLAMMATORY PROCESS

These are fever, leucocytosis, and elevation of the erythrocyte sedimentation rate Fever may be of any degree, but is usually moderate or high initially in children, and moderate or low grade in adults, it is irregular in type, and inclined to relapse; it may last only a few days, or it may continue for months. The temperature is normal in subacute rheumatism, and may be normal when polyarthritis is still active in acute attacks Leucocytosis is slight to moderate in the early phase of acute rheumatic fever, figures of 10,000 to 15,000 white cells per c.mm. being the rule The differential count may show a slight relative increase of polymorphs, but is often normal. In subacute rheumatism the total count is commonly between 7,000 and 10,000 per c.mm The sedimentation rate is by far the most valuable evidence of some active inflammatory process, and is often remarkably high when there are no other signs. Weekly readings have proved a reliable index of the course of the disease and of the degree of activity.

It will be appreciated that these three features are non-specific, they point to some inflammatory process, but they do not determine its nature. Secondary anæmia and loss of weight, or failure to gain weight, may be regarded in a similar light Undue tachycardia presents a more controversial problem whilst non-specific for the most part, and often due to anxiety, it may undoubtedly result from rheumatic carditis, and under certain circumstances may provide good evidence of it.

EVIDENCE THAT THE INFLAMMATORY PROCESS IS RHEUMATIC

1. *Polyarthritis.* Non-suppurative polyarthritis with sterile effusions into the large joints is characteristic. Involved joints may be painful, swollen, hot, flushed, and tender; on the other hand, slight effusion into a knee joint may be detected when there are no other signs or symptoms, or the patient may complain of joint pains when there are no signs, as in subacute rheumatism The older the patient the more often are the small joints affected, and it becomes increasingly difficult to distinguish rheumatic fever from rheumatoid arthritis. Pains and effusions tend to flit from joint to joint, one recovering as another is involved, but not necessarily. Occasionally, one knee or other large joint alone is inflamed, especially if previously injured, and may remain so for weeks or even for months; but minimal pains elsewhere may suggest its true nature Other forms of what is thought to be allergic polyarthritis, such as the dysenteric variety, may be indistinguishable except on other grounds For example, dysenteric polyarthritis is proclaimed by associated conjunctivitis and urethritis, and by its relation to dysentery

In subacute rheumatism, recurrent joint pains occur without effusion, and usually without fever or leucocytosis; but the sedimentation rate is raised "Growing pains" confined to the hips, knees, or ankles, mean subacute rheumatism; growing pains described in the muscles, ligaments, or tendons probably do not (Hawksley, 1939).

2 *Relationship to streptococcal infection.* The diagnosis is favoured if the symptoms follow a streptococcal sore throat, or some other streptococcal infection, including scarlet fever There is a latent interval of 1 to 3 weeks, usually 10 to 14 days. The significance of this relationship cannot be overstressed It appears to be fundamentally the same as the relationship between dysenteric polyarthritis and acute bacillary dysentery, or between gonococcal polyarthritis and gonorrhœa. Opportunity to study the dysenteric form was afforded by its frequency amongst the troops in North Africa and Italy in the second world war. It was characterised by acute poly-

and urethra yielded no pathogenic organisms. The provocative attack of dysentery was often abortive or very mild, and the latent period 10 to 14 days. A previous attack of dysentery was invariable, and was usually untreated. The evidence suggested that a fairly high degree of immunity was necessary for the development of the syndrome Gonococcal polyarthritis was equally common and behaved similarly, except that tenosynovitis replaced conjunctivitis, and urethritis was primary. The facts suggest that rheumatic fever is streptococcal polyarthritis, and bears the same relationship to the streptococcus as does dysenteric polyarthritis to the dysentery bacilli, and gonococcal polyarthritis to the gonococcus; but instead of con-

junctivitis, urethritis, or tenosynovitis, there may be carditis, chorea or marginate erythema

If there is no history of recent sore throat or other streptococcal infection, evidence of such may be afforded by an anti-streptolysin titre in the region of 200 Todd units. High titres do not prove that an illness is rheumatic fever, only that there has been recent hæmolytic streptococcal infection Similar proof may be obtained by finding that the patient's serum agglutinates an emulsion of hæmolytic streptococci at a titre of 1 : 200 It is highly improbable that any case of acute rheumatic fever, whether it be the first attack or a recurrence, will not show such serological changes

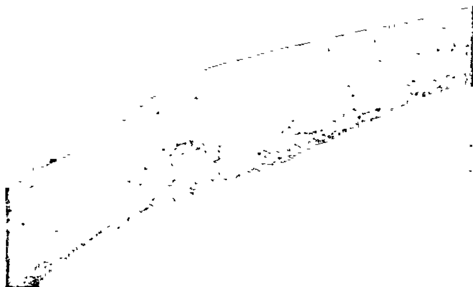
That continued hæmolytic streptococcal infection is not responsible for the disease may be proved by the lack of improvement after treatment with penicillin.

3. *Response to salicylates.* Joint pains and effusions in rheumatic fever commonly respond dramatically to sodium salicylate in initial doses of 15 to 20 grains (1 to 1.5 G.) three-hourly. Aspirin is also effective Other forms of polyarthritis (except perhaps that due to serum sickness) are not improved Only the exudative lesion and the associated fever respond, no effect is observed on proliferative lesions. Sodium salicylate is often used as a diagnostic test, but although a good one, it is not infallible

4 *Chorea* Rheumatic or Sydenham's chorea is mysterious in several ways. First, it has a solitary nature, preferring to occur alone rather than in the company of other rheumatic manifestations Secondly, it does not affect the sedimentation rate Thirdly, there is no specific rheumatic pathology in the brain (Shaw, 1929) Nevertheless, it is certainly part of the rheumatic state About 20 per cent of patients with chorea alone develop rheumatic heart disease, about 50 per cent develop other rheumatic manifestations with or without carditis (Sutton and Dodge, 1938), and most of the remainder have a familial link. Clinical features include spontaneous, involuntary, inco-ordinated movements, muscular weakness and alteration of tendon jerks, emotional instability, and some disturbance of higher cortical function. Occasionally, it is more or less confined to one side of the body Movements disappear during sleep.

The diagnosis must be made from common tics, and from hysteria in general. Reliance should be placed on the quality of the movements They are quick, complicated, elaborate, irregular and varied. The same movement is rarely repeated exactly The hands writhe and twist, the patient [illegible]

twitch of a tic. After protruding the tongue for inspection, she withdraws it like a lizard, snapping the jaws over it When the hands are held out, the wrist is flexed and the fingers hyper-extended The knee-jerk may be sustained, the leg being held up at the height of its extension for an appreciable interval before relaxation occurs.



(a)



(b)

Fig 8 02—Erythema marginatum.

Hysterical movements are more jerky, and show constant repetition Experience and familiarity with both conditions usually makes their distinction easy. The involuntary athetotic movements of encephalitis and Wilson's disease may be more confusing.

5. *Skin lesions* Petechiæ may occur in the skin or in the fundi in fulminating cases, but are in no way specific. Urticaria, erythema nodosum,



Fig 8 03—Erythema multiforme.

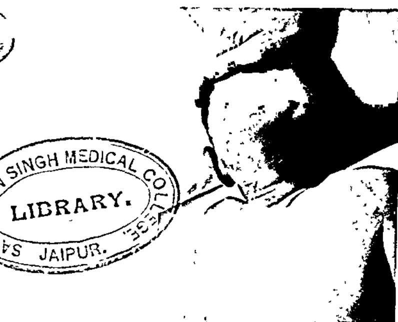
and erythema multiforme are sometimes seen, but they too are not specific. They are probably allergic skin reactions, and when associated with rheumatic fever may depend upon skin sensitisation to the streptococcus or to its toxins. Urticaria may be due to a host of antigens; erythema nodosum to the tubercle bacillus, the meningococcus, or other organisms; erythema multiforme is perhaps more closely related to the streptococcus.

Erythema marginatum (Barlow and Warner, 1881), a variety of erythema multiforme, is especially important because it is peculiar to the rheumatic state (Cheadle, 1889). It appears in rings, crescents, ovals, or in irregular

proximal part of the limbs There may be two or three lesions or dozens of them Sometimes the rash is at first composed of irregular erythematous macules (fig 8 03), but the centres soon clear, leaving spreading red margins (Perry, 1937). Erythema marginatum may be fleeting or remarkably persistent; as a rule, it is recurrent, and may reappear from time to time long after other manifestations of active rheumatism have subsided.



(a) On the knuckles



(b) On the back of the head

Fig 8 04—Subcutaneous rheumatic nodules.

Subcutaneous nodules are good examples of proliferative rheumatic lesions Like erythema marginatum they were first properly studied by Barlow and Warner (1881). Varying in size from something so small as to escape clinical perception to the dimensions of a Barcelona nut, they are usually attached to tendon sheaths, to the superficial surface of joint capsules or to other fascia, so that the skin rides over them freely. Sometimes they are partially attached to the skin and more or less move with it They are best seen on the knuckles (fig. 8.04a), on the back of the head (fig 8.04b), on the elbows or on the knees. In children they are practically diagnostic of rheumatic fever; but similar though usually larger and more persistent nodules may occur in Still's disease and in adult rheumatoid arthritis (Hawthorne, 1900). It is doubtful whether there is any fundamental difference between these nodules (Keil, 1938)

6. *Pulmonary signs.* Because of its non-specific clinical features, pleurisy rarely provides evidence of rheumatic fever, but it is not uncommon· Paul (1928) gave its incidence as 10 per cent It may be dry or it may give rise to a sterile straw-coloured effusion Response to salicylates is indifferent

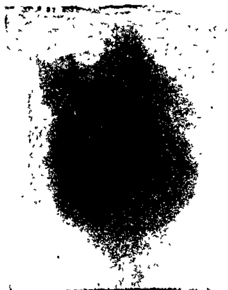


Fig 8 05—Skiagram showing rheumatic pneumonia in a girl

Rheumatic pneumonia is rare, occurring in only 1 to 2 per cent of active cases Symptoms are not spectacular There is no chill, breathing is not embarrassed, the respiratory rate is but little elevated, and fever is not necessarily higher than before Cough may be noted, but is rarely troublesome The sputum is scanty and tenacious, occasionally it is streaked with blood Physical signs include dullness to percussion, bronchial breathing and crepitations, appearing first here, then there. The transient and migratory nature of these signs is characteristic. Serial skiagrams confirm the presence of patchy wandering consolidation, or may show a variable broncho-pneumonic pattern (fig. 8 05) The white blood count is little altered Rheumatic pneumonia is not influenced by penicillin, sulphonamides or salicylates, fortunately it does not often appear to alter the course of the major illness

Most cases studied at autopsy have been unusually severe, and consolidation has been extensive and mostly lobar in distribution The affected parts

are bulky, have a peculiar succulent gelatinous appearance (Hadfield, 1938), and feel like indiarubber; in colour they are a homogenous rich purplish red (Naish, 1928; Eiman and Gouley, 1928), and later may be buff. Microscopically, the predominant finding is an extensive fibrinous exudate infiltrated with mononuclear and multinucleated cells Polymorphs and lymphocytes are scanty The cellular exudate is partly interstitial, but also lines the alveolar ducts and may fill the alveoli (Hadfield, 1938) There is associated hyperæmia and œdema Secondary fibroblastic reaction develops later, and when interstitial may be responsible for pulmonary hypertension (Gouley, 1938) Similar lesions have been produced experimentally by Rich and Gregory (1943).

Simple collapse of either lower lobe in the course of rheumatic fever may occur, and must not be confused with rheumatic pneumonia Its cause is obscure, but it may be connected with the long recumbent posture. It is seen in many serious illnesses which confine a patient to bed for a long time, e g typhoid fever Sometimes, of course, collapse of the left lower lobe may be due to pericardial effusion or to a greatly dilated heart Pulmonary congestion or œdema, and infarcts of the lung, should be recognised without difficulty

7 *Tolerance to Heparin* Patients with acute rheumatic fever show a remarkable tolerance to heparin, and possibly to other sulphated polysaccharides This is at present under investigation and may prove a useful test for the active rheumatic state (Abrahams, 1949)

EVIDENCE OF CARDITIS

To establish the diagnosis of rheumatic carditis may be one of the most difficult clinical problems in medicine. There are, however, six reliable signs when active rheumatism can be diagnosed on other grounds.

1 *Pericarditis* Transient or more persistent pericardial friction, with or without effusion, can be recognised in about 10 per cent of cases. Rheumatic pericarditis has no special features except that it is acute, often fails to alter the electrocardiogram, and leaves no important sequelæ. Effusion is common, samples are straw-coloured, sterile, and have the physical properties of an exudate. The effect of salicylates is doubtful. Paracentesis is only required to relieve cardiac compression or breathlessness due to collapse of the lung secondary to very large effusions. Clinical details are similar to those in other forms of pericarditis, and are described on page 341.

2. *Cardiac enlargement*. Displacement of the apex beat to the left is common in active rheumatic carditis, but not always easy to interpret. Any of the usual causes of cardiac displacement may be responsible, particularly collapse or partial collapse of the left lower lobe, and abdominal distension. The size of the heart is best determined by means of serial skiagrams (fig. 8.06); even then, enlargement is often a matter of opinion. Again, appreciable dilatation of the heart may occur in any fever, natural or artificial

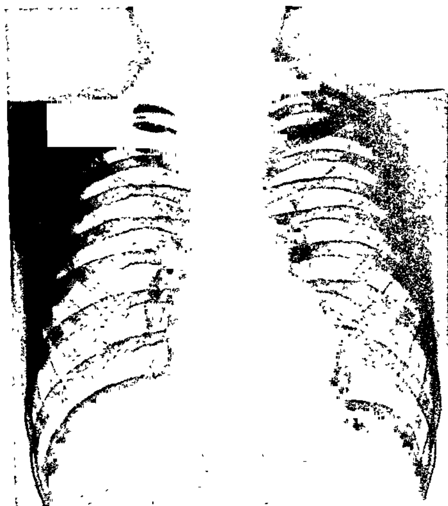


Fig 8 06 (a)—29th October 1948

Serial skiagrams showing rapid development of cardiac enlargement as a result of active carditis

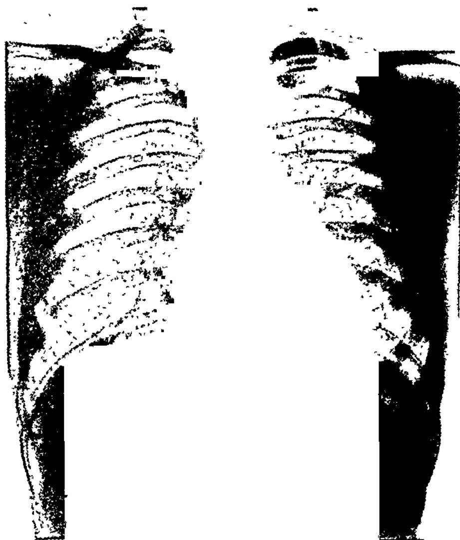


Fig 8 06 (b)—30th November 1948

Serial skiagrams showing rapid development of cardiac enlargement as a result of active carditis



Fig 8 06 (c)—9th December 1948

Serial skiagrams showing rapid development of cardiac enlargement as a result of active carditis

(Weens and Heyman, 1946), possibly because the cardiac output is raised. Unmistakable cardiac enlargement in a child with rheumatic fever is usually due to established valve lesions or to heart failure, if those are absent, however, it must be accepted as evidence of carditis

3 *Heart failure.* The development of congestive heart failure may be accepted as proof of carditis in a patient with active rheumatism. The jugular venous pressure then rises, the liver distends, and the cardiac output falls Œdema is uncommon. In otherwise uncomplicated cases, orthopnœa, paroxysmal cardiac dyspnœa and pulmonary œdema only occur when there is advanced aortic or mitral valve disease.

4 *Mitral diastolic murmur* The best evidence of carditis is the development of a soft mitral diastolic murmur (Carey Coombs murmur) in the absence of other signs of mitral stenosis Autopsies have confirmed the fact that this murmur may occur in active rheumatic carditis when the mitral valve is scarcely altered (Bland, White and Jones, 1935) It has therefore been suggested that its mechanism depends upon left ventricular dilatation, that it is related to the Austin Flint murmur, and to the soft mitral diastolic murmur which is occasionally heard in hypertensive or thyrotoxic heart failure But it must be pointed out that the Carey Coombs murmur is frequently heard when no enlargement of the heart can be demonstrated, and it is more reasonable to believe that some change in the structure of the mitral valve is responsible Whatever the explanation, there is no doubt that this murmur occurs early in the course of rheumatic carditis, and may disappear as activity subsides. More frequently, however, it is more or less persistent, or reappears on the least provocation, until pre-systolic accentuation proclaims the development of mitral stenosis (Carey Coombs, 1924) In a series at Taplow it was transient in 20 per cent (Wood, 1949)

5 *Aortic diastolic murmur* The development of an aortic diastolic murmur is equally good evidence of active carditis, if its previous absence can be guaranteed No other signs of aortic incompetence may be present, because the initial leak is small. Like the Carey Coombs murmur, a basal diastolic murmur is occasionally transient (10 per cent) When first heard, it may be remarkably short and its onset very slightly delayed, perhaps not developing until the left ventricular pressure has fallen below zero at the end of isometric relaxation.

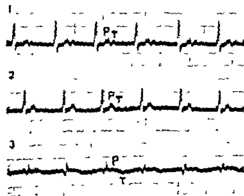


Fig 8 07—Electrocardiogram showing prolongation of the P-R interval in a case of active rheumatic carditis

6 *Electrocardiographic abnormalities* Obvious electrocardiographic changes are the exception rather than the rule;

thus an apparently normal graph in no way excludes carditis Serial records, however, may show transient prolongation of the P-R interval in about 10 per cent of cases (fig. 8.07) Normal conduction may be restored in 90 per cent of such cases by means of 1 to 3 mg of atropine sulphate

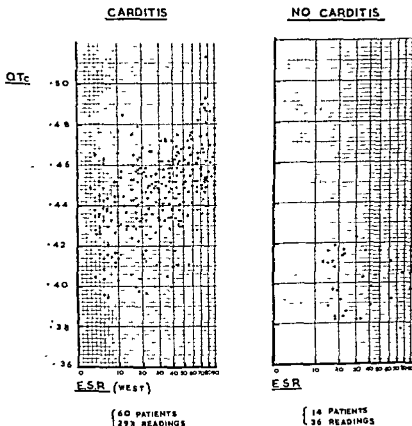


Fig 8.08—Graph showing QT_c plotted against the sedimentation rate in 60 cases of active rheumatic carditis and in 14 rheumatic fever controls without carditis

(*By courtesy of Dr Derek Abrahams*)

(Bruenn, 1937) Occasionally, partial heart block is persistent or progresses to complete block Nodal rhythm is sometimes seen, and rarely bundle branch block. Alterations of the RS-T segment usually denote pericarditis and exhibit the characteristic T_2 pattern

Prolongation of the Q-T interval was found by Taran and Szilagyi (1947) in practically all cases of active carditis, and this has been confirmed by

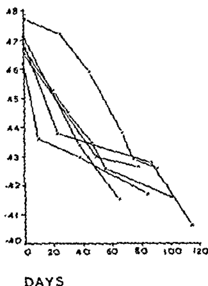


Fig 8.09—Behaviour of QTc in six cases of acute rheumatic carditis with rapid clinical recovery

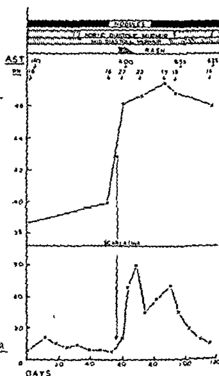


Fig 8.10—Prolonged QTc following a recurrence of active rheumatic carditis

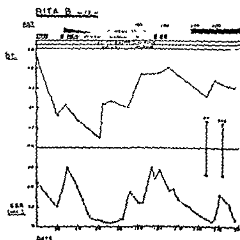


Fig. 8.11—Graph showing relapse due to getting up when QTc was still grossly prolonged

(By courtesy of Dr. Derek Abrahams)

cases of rheumatic fever without carditis has been plotted against the sedi-
will be seen that about 90 per cent
than 0.42 second, whereas all but
w this level. Fig. 8.09 shows the
behaviour of $Q\text{-}T_c$ in six typical cases of acute rheumatic carditis with rapid recovery. In fig. 8.10 a relapse is portrayed, it may be observed that $Q\text{-}T_c$ then remains grossly prolonged, although the sedimentation rate is falling towards normal. If the long $Q\text{-}T_c$ is ignored and the patient is allowed up, relapse is likely to occur (fig. 8.11)

Paroxysmal tachycardia may occur, but contributes little to establishing an etiological diagnosis, on the other hand, auricular fibrillation or flutter, developing in the course of active rheumatism, provides good evidence of carditis, although there is usually old-standing mitral stenosis as well

7. *Gallop rhythm* Gallop rhythm is more inconclusive. If it is presystolic, carditis is probable; if it is proto-diastolic it cannot be distinguished clinically from a normal third heart sound; if it is a summation gallop no conclusion can be drawn, though it is suspicious. Analysis may be difficult, for undue tachycardia is common in these cases, whilst carotid sinus slowing is minimal

8 *Systolic murmurs.* Finally, there is the problem of the apical systolic murmur. May it be disregarded, or does it indicate mitral valvulitis? Considerable experience is required to gauge its significance. The systolic murmur of mitral incompetence associated with active rheumatic carditis may be due to ring dilatation or to mitral valvulitis. It usually begins with the first heart sound and lasts throughout systole, in quality, it is commonly loud, smooth and blowing. Sometimes, however, the murmur may be rough or musical, and may be accompanied by a thrill When such murmurs offer the only evidence of carditis in children with rheumatic fever or chorea, chronic rheumatic heart disease develops subsequently in 45 per cent of cases; under similar circumstances, when the murmur is soft and unimpressive, subsequent rheumatic heart disease develops in only about 9 per cent (Boone and

It will be se
upon six featu
associated with active rheumatism. Gallop rhythm and a mitral systolic murmur, properly analysed and interpreted, may be suggestive, but are rarely conclusive

When there is no extra-cardiac evidence of active rheumatism, the problem is different. Under these circumstances pericarditis may be tuberculous or pyogenic, cardiac enlargement and failure may be due to other causes, mitral and aortic diastolic murmurs may be attributed to old valve lesions, and electrocardiographic abnormalities may have other explanations The differential diagnosis may then include congenital heart disease, tuberculous or pyogenic pericarditis, Pick's disease, subacute bacterial endocarditis, diphtheritic and other forms of carditis, pulmonary heart

disease, and anæmia. Nevertheless, rheumatic carditis may occur without evidence of rheumatism elsewhere, and active rheumatism may be afebrile, and associated with a normal white count and E.S.R. A diagnosis of rheumatic carditis is therefore justified if the cardiac lesion is characteristic, even when there is no other evidence of rheumatism, or even of an inflammatory state Again, if there is evidence of an inflammatory state, a suitable cardiac lesion may proclaim its rheumatic nature when there is no other rheumatic manifestation.

COURSE AND TREATMENT

All cases of acute or subacute rheumatic polyarthritis should be put to bed and treated with sodium salicylate, 15 to 20 grains (1 to 1 5 G.), combined or not with twice as much sodium bicarbonate, three-hourly (Lees, 1904), until relieved, or until ringing in the ears and deafness pronounce intoxication, when the interval between doses may be increased to four hours. The effective blood level of salicylates is about 30 mg. per cent. Fever, pain, and joint effusions usually subside quickly, but proliferative lesions, including carditis, are resistant. The action of salicylates is uncertain it has been suggested that they may inhibit antibody formation (Derick, Hitchcock and Swift, 1927–8). Toxic effects are minimised by alkalis: this has been attributed to an increased rate of salicylate excretion in their presence (Parker, 1947, 1948) Peters (1947), however, did not find that this materially affected the blood level, and claimed that alkalis enhanced the therapeutic benefit of salicylates Toxic effects include petechiæ associated with prolongation of the prothrombin time (Link *et al*, 1943) Fatal hæmorrhagic encephalopathy has been reported (Ashworth and Mckemie, 1944) Circulating prothrombin can usually be restored by means of vitamin K in doses of 10 to 50 mg. (Shapiro, 1944)

When the patient has been free from symptoms for a week, or if he fails to derive benefit, salicylates should be stopped. If clinical relapse follows, no harm is done, for the exudative lesion is relatively innocent, and is soon controlled by another course.

By far the best index of activity is the E S R., which should be measured weekly, and as a rule the patient should not be allowed up until it is normal. This applies especially to children, in whom carditis should be assumed *for purposes of early management* Adults without evidence of previous or present carditis may be treated more leniently, and may be allowed up as soon as they appear well enough on clinical grounds. The duration of bed rest varies between a week or two and several months, according to the severity and persistence of the active process. If patients are allowed up too soon, swift relapse is the rule.

Joints may be partly or completely immobilised in the position of maximum comfort in the acute phase, and some soothing lotion, such as oil of wintergreen or lead and opium, may be applied. Contractures are not a

feature of rheumatic fever, but foot-drop should be prevented, and elbows and knees should not be immobilised too long.

Recent work at the Mayo Clinic on the beneficial effect of compound E (17-hydroxy-11-dehydrocortico-sterone) on rheumatoid arthritis (Hench *et al*, 1949) has provided a new approach to the treatment of rheumatic states in general; but it is too early to comment on the results so far obtained in rheumatic fever. Joint pains appear to be relieved as quickly as with salicylates, but a beneficial effect on carditis has yet to be demonstrated Cortisone (adrenal cortical hormone) is the active agent the liberation of increased quantities of natural cortisone may be brought about by the administration of A.C.T.H (adrenocorticotropic hormone of the pituitary).

Sulphonamides and penicillin are of no value, except perhaps in the treatment of the provocative streptococcal infection or if the latter persists Tonsillectomy is only necessary if there is chronic sepsis, or if there is recurrent tonsillitis; it has little influence on the disease, and does not prevent relapse or recurrence (Ash, 1938) A good nourishing diet, fresh air, vitamins, especially vitamin C, appropriate treatment of secondary anæmia, and high morale are more important

Chorea usually lasts 6 to 12 weeks. Patients should be put to bed during the active phase, and may need heavy sedation If there is no evidence of carditis they may be allowed up when recovery begins They should be kept away from school and from social engagements until well

Carditis requires absolute rest. Little else is of lasting value. Digitalis is helpful when there is congestive heart failure, and although the therapeutic dose is said to be close to the toxic, ill effects have not been observed at Taplow. Mercurial diuretics and a low sodium diet are rarely necessary.

Absolute rest means that the patient is allowed to do nothing for himself, he is washed and fed, and must use bed-pan and urine bottle Diet should be light and constipation avoided In the past it was usual to insist on nursing the patient in the horizontal position, with one low pillow, but it is clear from experience gained in the treatment of angina decubitus and of paroxysmal cardiac dyspnœa, and from certain direct investigations in man, that the cardiac output, and therefore the work of the heart, is greater in the horizontal than in the upright position, owing to the influence of gravity on the venous filling pressure. It is therefore logical to nurse patients with carditis in the sitting posture. The wisest course may be to chose the position of maximum comfort, whether lying or sitting, unless there is failure, when the latter should be insisted upon

Convalescence from carditis should be extended over several months, the régime being similar to that for pulmonary tuberculosis Relapse is common and may be due to over-exertion, exposure, emotional upset, cold damp weather, and to almost any infection Relapse follows the advent of the responsible agent immediately, and must be distinguished from a recurrence or second attack of rheumatic fever, in which streptococcal infection

is always to blame, and following which a latent interval can usually be recognised. To avoid such infection, prophylactic sulphonamide may be given in doses of 1 to 2 G. daily whenever some risk is encountered At least one recurrence occurs in two-thirds of all cases, usually within three years (Roth, Lingg and Whittemore, 1937)

It is as important to prevent cardiac neurosis in patients with organic heart disease as it is in those without This is a difficult task in susceptible individuals, for reassurance cannot very well be unconditional. Rheumatic carditis may be symptom free, and pass without influencing the subject's activities at all Thus only about 55 per cent of cases of mitral stenosis give a history of the original attack (Parkinson and Hartley, 1946). Many others are only restricted by subacute rheumatism Little immediate harm comes to these patients, indeed there is no direct evidence that subsequent development of mitral stenosis could have been prevented by bed rest at the time of active inflammation. It follows that failure to diagnose carditis when it is present in rheumatic fever is not necessarily disastrous. On the other hand, its diagnosis in error may not be far short of it, for the resulting cardiac neurosis, which is so common, may be life-long and may be more incapacitating than organic heart disease Physicians should be more aware of their responsibility in this respect. Too much emphasis is laid on overlooking a mild lesion, not enough on finding what is not there. The most common mistake is to misinterpret tachycardia. A patient confined strictly to bed for several weeks with rheumatic fever is fully aware that his heart may be involved, and is likely to become nervous on that account Tachycardia may then be due to anxiety. Again, the autonomic nervous system is frequently disturbed by fever and infections of all kinds: tachycardia, dizziness, headache and fatigue may result, especially during convalescence when activities are resumed Such findings call for reassurance and rehabilitation, not for alarm and further rest.

In the absence of diagnostic evidence of carditis throughout the active phase of rheumatic fever, subsequent medical management should be based on the assumption that none existed, not upon the fear that it escaped recognition; and patients should be sent for convalescence as after any other fever of equal severity This attitude is based, not on the belief that carditis does not occur in a certain percentage of children with rheumatic fever, but on the fact that if it does occur in an indetectable degree, it is either of no consequence, or it is not aggravated by this kind of management; and on the fact that the over-cautious attitude breeds neurosis.

MORTALITY

The mortality rate from active rheumatic carditis in childhood and adolescence is about 6.5 per cent (Scott, 1943). About half the fatalities have some important complication. In the majority (62 per cent) death occurs within five years of the initial attack (Bland and Jones, 1938). Bad

prognostic omens include rapid cardiac enlargement, obvious nodules, pericarditis, auricular fibrillation and congestive heart failure Sudden unexpected death is rare in rheumatic carditis, in contrast to its frequency in diphtheritic and other forms of toxic carditis. There were only three such instances among a group of 7,165 cases of active rheumatic fever reported by Griffith and Huntington (1946); coronary angiitis was blamed

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CHAPTER IX

INACTIVE RHEUMATIC HEART DISEASE

RHEUMATIC carditis refers to active inflammation of the heart. The after-effects, which include valvular sclerosis, patchy myocardial fibrosis, and adherent pericardium, are best described under the general heading of rheumatic heart disease, to which the appropriate anatomical abnormality may be appended. Thus we may speak of rheumatic heart disease with mitral stenosis.

Incidence. About 5 per cent of healthy young adults give a previous history of rheumatic fever in childhood (Parkinson and Hartley, 1946). It is clear, therefore, that all patients who have rheumatic fever do not later develop clinical rheumatic heart disease. According to Carey Coombs (1924), 50 per cent of children who have their first attack of rheumatic fever before they are five years old, and 25 per cent of those whose first attack occurs after the age of ten, subsequently develop rheumatic heart disease

From large samples of the younger male population of Great Britain examined for military service between 1939 and 1945, it was calculated that there were about 240,000 cases of rheumatic heart disease of both sexes between the ages of 18 and 44 in Great Britain at that time, or about 7 per cent of the population in that age-group (Parkinson, 1945). Rheumatic heart disease accounts for approximately 25 per cent of all cases of heart disease in temperate climates, and causes about 16,000 deaths annually in England and Wales.

Practically all clinical cases of inactive rheumatic heart disease have one or more valve lesions. The mitral valve is involved in 85 per cent, the aortic in 44 per cent, the tricuspid in 10 to 16 per cent, and the pulmonary in 1 to 2 per cent (Cabot, 1926) Mitral disease is more common in females in the ratio of 3 : 2; aortic valve disease is equally more common in males.

LESIONS OF THE VALVES

1. *MITRAL INCOMPETENCE*

In the last century this was the most common valve lesion diagnosed Owing to the exertions of Mackenzie, Lewis, Parkinson, and others, recent years have witnessed a *diagnostic revolution*, so that now a physician who asserts that a patient has organic mitral incompetence must be very sure of his grounds. The change in outlook has saved a host of normal subjects from invalidism. Nevertheless, mitral incompetence is a real entity, and the

whole problem must be critically examined. The difficulty lies in the interpretation of apical systolic murmurs. In the past these were nearly always attributed to mitral incompetence, and the latter was believed to be the consequence of valvular disease. It is now known, however, that apical systolic murmurs may be cardiac or extra-cardiac, and if cardiac may be due to mitral incompetence or to some other factor, mitral incompetence itself may be organic or functional. These possibilities will be considered in detail.

EXTRA-CARDIAC MURMURS

The heart expanding in diastole may press upon a portion of lung so that the latter, suddenly decompressed in cardiac systole, sucks in air, and gives

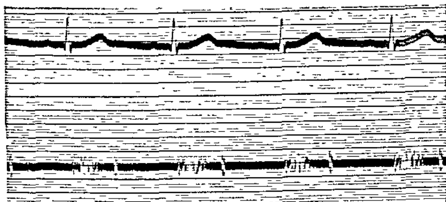


Fig 9 01—Phonocardiogram showing an innocent systolic murmur at the mitral area

(By courtesy of Dr Aubrey Leatham)

rise to a systolic vesicular murmur. This is soft and varies with respiration and with change of posture Normal friction between two healthy serous membranes, adequately lubricated, may give rise to a murmur indistinguishable in quality from the ordinary soft apical systolic bruit (Ortiz, 1933) Such murmurs are probably exaggerated by overaction of the heart as in thyrotoxicosis, anæmia, and the anxiety states

Innocent systolic murmurs have been said to begin some time after the first heart sound (Evans, 1947), but this is not generally accepted, many such murmurs beginning early in systole (fig 9 01).

CARDIAC MURMURS

(*a*) *Without mitral incompetence* In aortic stenosis, a systolic murmur, undoubtedly produced at the aortic valve, is sometimes heard best at the apex beat. It follows that a functional murmur arising at the base may also be heard best at the apex beat. It should be understood that this site commonly represents the apex of the left ventricle, and is therefore in direct

communication with the aorta. Functional murmurs may result from turbulence at the root of the aorta in normal subjects, especially when the cardiac output is increased Harsh or musical apical systolic murmurs may occur in hearts which offer no obvious mechanical explanation when examined later after death. It is thought that these may be due to unusual vibration of the chordæ tendineæ.

(*b*) *Mitral incompetence (functional)* Experiments after death show that the aortic valve is competent and the mitral incompetent when water is poured into the aorta or left ventricle respectively. During life, proper mitral closure depends upon adequate constriction of the mitral ring, and upon sufficient slackness of the inelastic chordæ tendineæ, which, acting as "guy ropes", anchor the valve cusps to the wall of the left ventricle. When that chamber is dilated, the mitral ring is expanded, and stretched chordæ tendineæ may prevent the cusps falling back sufficiently to come into close apposition. Functional mitral incompetence in left ventricular failure is therefore more or less inevitable. It may also complicate left ventricular dilatation in the hyperkinetic circulatory states and in any form of carditis. Functional mitral incompetence of this kind seems to occur naturally in some otherwise normal hearts, perhaps due to some slight fault in architecture It is of no consequence.

(*c*) *Mitral incompetence (organic)* Organic mitral incompetence refers to disease of the mitral valve which prevents its proper closure. It is nearly always rheumatic, and may be associated with shortening and thickening of the chordæ tendineæ. In the great majority of cases the mitral ring and base of the cusps are also sclerosed, resulting in mitral stenosis. In clinical diagnosis, the latter is so much the more important that the other is hardly worth mentioning in its company But if there is no stenosis, organic mitral incompetence leads to a well-defined clinical picture During systole, the left auricular pressure and volume rise well beyond normal limits, and the chamber expands visibly During diastole, the left ventricle becomes abnormally distended as a result of this high-filling pressure. The stroke volume propelled into the aorta thus remains normal. In other words, increased distension of the left ventricle compensates for the leak. In time both the left auricle and ventricle may become considerably enlarged.

The diagnosis of organic mitral incompetence is based upon the following features:

1. An impressive mitral systolic murmur This is not necessarily loud or harsh; but it usually begins early, lasts throughout systole, and has a characteristic blowing quality (fig. 9 02a) The intensity of the murmur should not be altogether disregarded, as follow-up studies on children with suspected rheumatic carditis have demonstrated clearly that those with loud murmurs are five times more likely to develop chronic rheumatic heart disease than those with soft murmurs (Boone and Levine, 1938; Kuttner and Markowitz, 1948) The loud late systolic murmur, which seems to increase in intensity as it merges into the second heart sound

(fig. 9.02b), though sometimes innocent, may undoubtedly be due to organic mitral incompetence: thus it may be associated with mitral stenosis or with expansile pulsation of the left auricle.

2 Mitral systolic thrill. As a general rule, a thrill means organic disease, but there are exceptions. Conversely, many cases of mitral incompetence

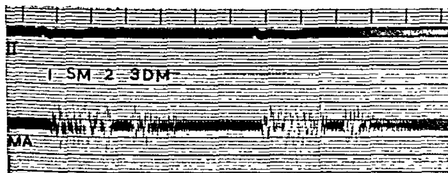


Fig 9 02 (a)—Phonocardiogram showing a systolic murmur due to organic mitral incompetence

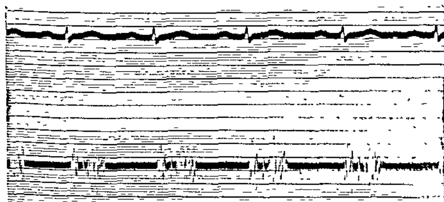


Fig 9 02 (b)—Loud late systolic murmur in a case of organic mitral incompetence

(By courtesy of Drs William Evans and Aubrey Leatham)

have no thrill. When there is aneurysmal dilatation of the left auricle, the
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ing left auricular dilatation in the antero-posterior or right anterior oblique position do not distinguish mitral incompetence from mitral stenosis (fig.

2.33), but when viewed fluoroscopically the former is recognised by expansile pulsation of the left auricle during ventricular systole. If cardiac movements are correctly interpreted, this is diagnostic Kymography facilitates analysis.

There are two distinct clinical types of organic mitral incompetence: those that develop aneurysmal dilatation of the left auricle, and that behave like cases of mitral stenosis; and those that develop increasing left ventricular enlargement, and which behave more like cases of aortic stenosis (with which they are readily confused).



The prognosis of organic mitral incompetence is fair: cases with aneurysmal dilatation of the left auricle usually die between the ages of 30 and 45, those with large left ventricles may be expected to survive to the age of 50 or so, but then succumb rather suddenly to irreversible heart failure.

2 *MITRAL STENOSIS*

Pathology Reparative fibroblastic proliferation, already described as part of the rheumatic lesion, has unfortunate results when situated at the base of the mitral cusps or in the mitral ring; for here subsequent contracture leads to stenosis of the valve This is the common sequel of rheumatic carditis, as the base of the valve is its most vascular part, and therefore the most effected The lesion takes at least two years to develop sufficiently to give rise to physical signs, usually much longer (Carey Coombs, 1924). The degree of narrowing varies from an amount insufficient to have any effect on function, to tight button-hole stenosis with an orifice which barely admits a pencil Calcification is common in elderly subjects. Associated mitral incompetence is the rule, but is relatively unimportant.

Disturbance of function. The blood flow being obstructed at the mitral valve, the pressure rises in the left auricle and pulmonary veins This at first compensates for the obstruction and insures full left ventricular filling, the greater speed of blood flow through the mitral orifice making up for its smaller cross-section.

Next, the increased pressure in the left auricle and pulmonary veins

causes a rise in pulmonary arterial pressure, so that the normal pressure gradient is maintained. There is little to support the view that pulmonary hypertension in mitral stenosis does not depend on the left auricular pressure, but upon some hypothetical reflex or upon rheumatic pulmonary arteritis (Gouley, 1938). On the contrary, left auricular pressures when measured at thoracotomy may be very high indeed, and amply explain mean pulmonary artery pressures over 30 mm Hg.

When relatively healthy, the left auricle hypertrophies, and so increases the presystolic pressure gradient between auricle and ventricle. This contributes further to adequate left ventricular filling. Not infrequently, however, myocardial fibrosis weakens the left auricle and favours dilatation of that chamber. Sooner or later left ventricular filling is hampered, and the cardiac output tends to fall or cannot meet the demands of effort. The pulse volume becomes small and the aorta and left ventricle hypoplasic.

At the same time the right ventricle hypertrophies to cope with pulmonary hypertension, and the pulmonary artery dilates. There is a permanent shift in blood distribution, more being held in the pulmonary circulation and left auricle than usual, and correspondingly less on the systemic side. The vital capacity and lung volume are thus reduced and the pulmonary circulation time prolonged. If the blood volume does not increase, compensatory systemic vasoconstriction results, adapting the systemic vascular capacity to its reduced contents, and so maintains the blood pressure. Hence the small pulse is firm, and the skin is cold, pale, and cyanotic.

Dyspnœa at this stage is not due to an increase of carbon dioxide acting on the respiratory centre, nor to reduced oxygen tension acting on chemoreceptors in the carotid sinus, for the gaseous exchange is still normal. It is intimately connected with the engorged pulmonary circulation. This excites a respiratory reflex through pulmonary vagal afferents whereby breathing becomes quicker (Harrison, 1935). The Hering-Breuer reflex is ordinarily concerned with limiting the depth of inspiration and is initiated by stretch-receptors which are probably situated in the walls of the alveolar ducts. The mechanism is inhibitory and is abolished by section of the pulmonary vagal afferents. Just how vascular engorgement increases the activity of the stretch-receptors, if these two reflexes are the same, is not clear.

Likewise, cyanosis is not due to reduction of the arterial oxygen saturation, for this does not occur unless there is pulmonary œdema or other late changes in the lung parenchyma. Cyanosis is usually attributable to peripheral vasoconstriction.

In an attempt to increase the cardiac output, the venous filling pressure tends to rise, especially on effort, and for a time this mechanism may prove successful, but sooner or later paroxysmal cardiac dyspnœa or congestive heart failure develops.

Clinical features. Well established mitral stenosis is characterised clini-

cally by a malar cyanotic flush on a pale background, cold cyanosed extremities, a small firm pulse, tapping cardiac impulse, slapping first heart sound, mitral diastolic murmur with or without thrill and with or without presystolic accentuation, and by a loud pulmonary element of a normally split second heart sound at the base. The diagnosis may be confirmed by means of fluoroscopy and electrocardiography

The mitral diastolic bruit can always be recognised, wherever it is heard, by the presence of an appreciable gap between it and the second heart sound (fig 9 04) If the diastolic blood pressure is 80 mm of mercury, then

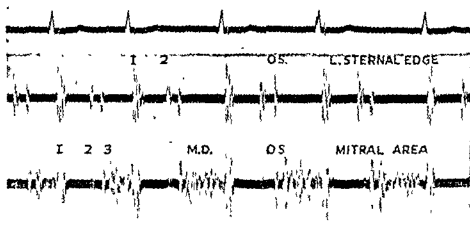


Fig 9 04—Phonocardiogram showing a mitral diastolic murmur following the third heart sound in a case of mitral stenosis

(By courtesy of Dr Aubrey Leatham)

the pressure within the left ventricle is just below this level when the aortic valve shuts, i.e. at the moment of the second heart sound. As the pressure within the left auricle is then much lower, the mitral valve remains closed and cannot open until the intraventricular pressure has fallen below the auricular. The duration of this pause varies from 0 06 to 0 15 second (Braun-Menendez and Orias, 1935) The opening of the mitral valve may give rise to a sharp sound—the opening snap of Potain—and coincides with the summit of the "v" wave of the jugular phlebogram (Margolies and Wolferth, 1932). Moreover, the mitral diastolic murmur may be delayed still further, for turbulence may not develop until the moment of rapid ventricular filling, which coincides with the third heart sound and with the lower half of the downstroke of the "v" wave of the jugular phlebogram. The only occasions on which the gap may not be recognised are when gross mitral incompetence causes a systolic murmur

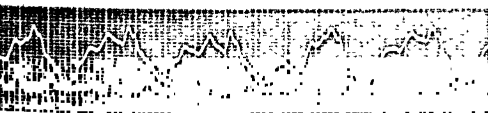


Fig 9 05—Phonocardiogram at the apex beat in a case of patent ductus, showing a functional mitral diastolic murmur

(By courtesy of Drs Frances Gardner and Max Zoob)

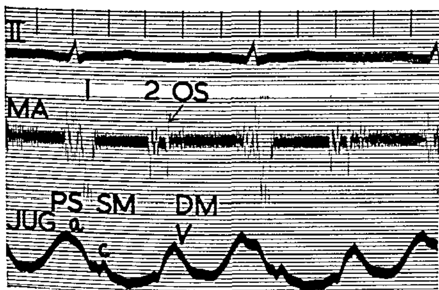


Fig 9 06—Phonocardiogram showing a crescendo presystolic murmur timed against the electrocardiogram and phlebogram

(By courtesy of Drs William Evans and Aubrey Leatham

that continues during the period of isometric relaxation. The characteristic mitral diastolic bruit is low-pitched and rumbling, is heard best with a bell stethoscope, and may be exaggerated when the patient lies on the left side, or when the cardiac output is increased by means of exercise or amyl nitrite. The recognition of this murmur often depends upon the examiner's ability to concentrate upon that phase in diastole in which he knows it should arise, to the exclusion of all other sounds. Never was attention directed to a preconceived sound more amply rewarded. Presystolic accentuation (Fauvel, 1843) (fig. 9 06) depends upon auricular contraction (Gairdner, 1861) and necessarily disappears when the auricles fibrillate Occasionally, functional pulmonary incompetence causes a basal diastolic murmur down the left border of the sternum—the Graham Steell murmur (Steell, 1888). There is no sure way of distinguishing this murmur from that of aortic incompetence, but it tends to be more local, is placed rather higher on the left, and may be lower in pitch. Interpretation, however, is more safely based upon the presence of gross dilatation of the pulmonary artery on the one hand, and upon other evidence of aortic valve disease on the other

The mitral diastolic murmur is not quite pathognomonic of mitral stenosis, for turbulence giving rise to an identical bruit may occur in active rheumatic carditis, gross aortic incompetence (Austin Flint, 1862), and when left ventricular dilatation is associated with an increased pulmonary blood flow, as in patent ductus arteriosus (fig. 9.05), ventricular septal defect, thyrotoxicosis and anæmia.



Fig 9 07—Skiagram of a case of mitral stenosis showing dilatation of the left auricle between the pulmonary arc and the left ventricle. The left auricle may also be seen at the right border of the heart above and overlapping the right auricle.

X-ray appearances. Fluoroscopy reveals characteristic changes in the size and shape of the heart. The aorta is small, the pulmonary arc dilated, and the hilar vessels engorged. The dilated left auricle often causes a bump on the left border of the heart between the pulmonary artery and left ventricle, a prominence which is seen in no other condition (fig. 9 07). Left auricular enlargement is seen best in the right anterior oblique position, with barium in the œsophagus (fig 9 08)



Fig 9 09—Skiagram of a case of mitral stenosis showing dilatation of the left auricle in the left anterior oblique position



Fig 9 10—Skiagram of a case of mitral stenosis showing miliary nodules in the lungs due to hæmosiderosis



Fig 9 11—Angiocardiogram in a case of mitral stenosis Showing the left auricle in the second oblique position

As a rule, the chamber enlarges backwards and to the right, and may often appear in the antero-posterior view just above and overlapping the right auricle (fig. 9.07). Occasionally, it enlarges backwards and to the left, when it may be seen best in the left anterior oblique position, just above and overlapping the shadow of the left ventricle (fig. 9 09 and 9 11). Appearances in the lung fields occasionally resemble those of miliary tuberculosis (fig. 9 10). They have been ascribed to pulmonary hæmosiderosis similar to that seen in certain hæmolytic anæmias of childhood (Gumpert, 1947).

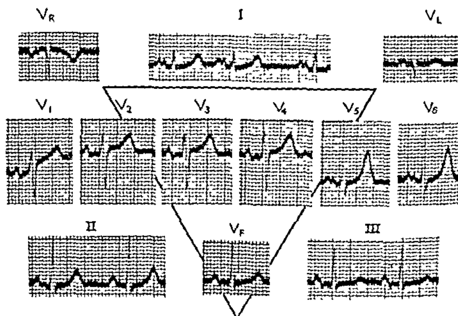


Fig 9 12—Electrocardiogram in a case of mitral stenosis showing widened bifid P waves particularly in leads 1, 2, V5 and V6 The heart is vertical

Angiocardiograms prove that the bump on the left border of the heart between the pulmonary arc and left ventricle is the left auricle, not the conus of the right ventricle

Electrocardiography. Electrocardiograms commonly show widened bifid P waves, particularly in leads *1, 2,* V4, V5 *and V6 (fig. 9 12), indicating* left auricular enlargement; they are not necessarily very conspicuous (fig. 9 13). Occasionally, P is tall and sharp (fig. 9 14), as in pulmonary heart disease, indicating right auricular enlargement. Pulmonary hypertension or tricuspid stenosis may then be responsible. When there is considerable right ventricular enlargement, partial right bundle branch block is common, although standard limb leads may give little indication of it (fig 9.15) Right axis deviation in mitral stenosis is usually due to a vertical heart, the QR complex from the left ventricle being transmitted to lead VF (fig. 9.12);

Fig 9 13—Electrocardiograms showing the P waves in 18 unselected cases of mitral stenosis

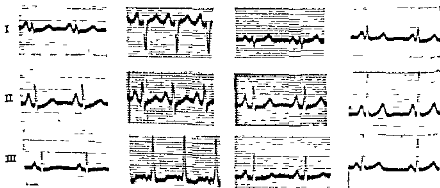


Fig 9 14—Standard lead electrocardiograms in 4 cases of mitral stenosis showing tall sharp P waves like those seen in pulmonary heart disease.

or it may be due to partial right bundle branch block, the RS complex from V6 being transmitted to VL, and the RSR pattern from V1 being transmitted to VF, the heart then being electrically horizontal. In rare instances a QR complex may be seen in lead V1: this is probably due to clockwise rotation about the longitudinal axis (viewed from below), and represents potentials at the back of the heart.

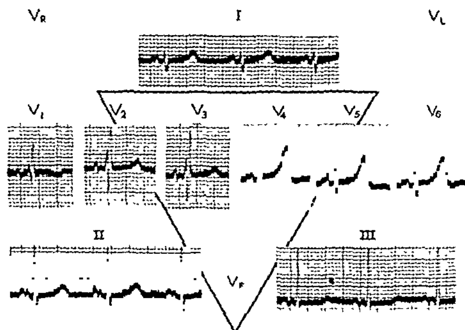


Fig 9 15—Electrocardiogram in a case of mitral stenosis showing partial right bundle branch block

Functional studies The vital capacity and lung volume are reduced and the arm-to-tongue circulation time is prolonged in proportion to the degree of pulmonary congestion. The jugular venous pressure and right auricular pressure tend to be slightly elevated when there are symptoms of effort intolerance – before the development of congestive heart failure proper. When, clinically, the venous pressure is normal, it may yet be possible to demonstrate its conspicuous elevation on effort This is good evidence of limited cardiac reserve.

The right ventricular pressure, measured by means of cardiac catheterisation, is usually somewhat raised, mean figures mostly ranging between 10 and 30 mm Hg above the mean right auricular pressure. In tight stenosis with paroxysmal cardiac dyspnœa, however, extremely high pressures are found (30–60 mm Hg).

gestive failure develops, it is always low The arterio-venous oxygen difference is then increased.

Complications

1. *Auricular fibrillation* Auricular fibrillation is common, occurring sooner or later in 50 per cent of cases Its incidence bears a linear relationship to the age of the patient When it occurs in adolescents or in young adults it nearly always signifies rheumatic activity. Although it may occur in paroxysms at first, it soon becomes permanent, and attempts to restore normal rhythm with quinidine are apt to be fruitless and dangerous. Auricular flutter is less common, but by no means rare. In fact, mitral stenosis is the most common cause of flutter Such changes of rhythm are important because they may provoke heart failure and because they increase the risk of embolism

2. *Congestive heart failure.* Paroxysmal cardiac dyspnœa and pulmonary œdema are due to mitral stenosis in about 9 per cent of cases, when they represent considerable obstruction at the mitral valve and a strong right ventricle acting with normal rhythm Attacks are prone to occur on effort, when the right ventricle pumps more blood into the lungs than can escape through the tight mitral orifice They are readily induced by a rigor Congestive heart failure may occur with normal rhythm or may follow the onset of auricular fibrillation or flutter Recurrent rheumatic activity, intercurrent infection, pregnancy and heavy manual work are the most important provocative factors

3 *Hæmoptysis* was first correlated with mitral stenosis by Wilson in 1830 (Rolleston, 1941) There are two common causes: rupture of an engorged vessel, and pulmonary infarction Hæmorrhage from the former is apt to be short and brisk, from the latter, prolonged Pulmonary apoplexy usually occurs with normal rhythm, pulmonary infarction with auricular fibrillation and heart failure

4 *Systemic emboli* Clots form in the dilated left auricle in 12 per cent of all cases of mitral stenosis, and in 24 per cent of those with auricular fibrillation (Davis and Weiss, 1931) Ill-advised quinidine therapy may excite the liberation of such a clot

5 *Laryngeal palsy* Gross left auricular dilatation may compress the left recurrent laryngeal nerve and paralyse the left vocal chord (Ortner, 1897) Dilatation of the left pulmonary artery assists in the process (Fetterolf and Norris, 1911) Huskiness of the voice follows The condition is not rare in advanced mitral stenosis

6 *Collapse of the lung* Gross enlargement of the left auricle may com- [illegible]

of recurrent bronchitis Rhonci may obscure the characteristic murmur and the correct diagnosis may then be overlooked

8. *Bacterial endocarditis.* Acute or subacute bacterial endocarditis may complicate mitral valve disease in any stage of its history, including that of active rheumatism, and should always be borne in mind.

Associated diseases. Rheumatoid arthritis (page 256) and arachnodactyly (page 255) have already been discussed. Essential hypertension was found in 28 per cent of 150 cases of mitral disease reported by Berconsky and Neuman (1945), but was regarded as fortuitous. Coincident thyrotoxicosis is not rare. Despite the fact that rheumatic fever occasionally causes coronary arteritis, angina pectoris is very uncommon in mitral stenosis, and when present may be attributed to independent coronary atherosclerosis. The incidence of tuberculosis in cases of mitral stenosis is lower than in the general population

Course and prognosis. The average life history of rheumatic heart disease with mitral stenosis may be summarised as follows The initial rheumatic attack occurs between the ages of 8 and 12 Severe cases die within ten years, these are nearly all still active Those who make a good immediate recovery usually remain free from symptoms for about twenty years Breathlessness on exertion sufficient to limit the patient's ordinary activities then develops, and progresses to congestive heart failure within two or three years The average age at death is about 35. Patients who die with normal rhythm tend to be younger, the average age of death for this group being 29, the average age of death in patients with auricular fibrillation is 38 (De Graff and Lingg, 1935) The duration of auricular fibrillation averages but two to three years. Such figures provide a useful basis upon which to assess prognosis in any particular case, but individual variation is great, some patients dying in adolescence, others reaching old age. Each should be judged on its own merits, due consideration being paid to effort tolerance, heart size, rhythm, congestive heart failure, and particularly to recurrent or persistent rheumatic activity Life expectancy is little influenced by the presence of other valve lesions.

Persistent active rheumatic carditis is probably the most important factor determining prognosis. Thus, De La Chapelle, Graef and Rottino (1934) demonstrated Aschoff nodes in 86 per cent of cases dying under 40 years of age, and in 33 per cent of cases over 40 Werner (1936) found activity in 66 per cent of all cases of rheumatic heart disease which had died from congestive failure

3. *AORTIC INCOMPETENCE*

Pathology. Rheumatic inflammation of the aortic valve may cause immediate aortic incompetence. Healing usually results in thickening, retraction, and distortion of the cusps, with permanent regurgitation In addition, the cusps often become adherent to one another at their bases (fusion of the commissures), so that some degree of aortic stenosis is usual. Secondary calcification is common, especially when there is stenosis.

Effect on function. The stroke-volume of the left ventricle is increased by

an amount which is at least equal to the quantity of blood which leaks back during diastole. The fibres of the left ventricle become considerably stretched in diastole, the force of the heart beat is therefore augmented according to Starling's law. The initial tension is increased, isometric contraction is abbreviated, maximum pressure is higher than normal and is attained earlier in systole, the ejection phase is shortened, and the pressure then falls away steeply in late systole. In other words, the shape of the pressure curve is altered so that early systole is loaded and late systole unloaded (Wiggers, 1935) The large quantity of blood pumped so quickly and powerfully into the relaxed arteries during early systole causes an abrupt percussion wave followed by late systolic collapse. The low diastolic

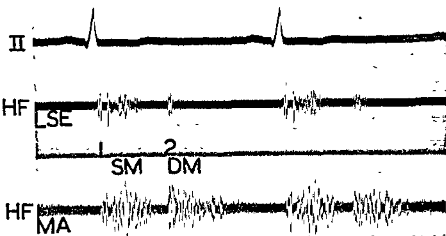


Fig 9 16—Phonocardiogram illustrating a diminuendo aortic diastolic murmur

pressure is due partly to the aortic reflux and partly to peripheral vasodilatation, the latter encourages forward flow. Both add to the collapsing quality of the pulse

The cardiac output per minute remains about normal or may be even a little raised, as it is in patent ductus arteriosus and arterio-venous aneurysm, which have much in common with aortic incompetence Effort tolerance is usually remarkably good until the disease is well advanced Sooner or later, however, left ventricular failure develops, often suddenly and unexpectedly The heart then becomes overloaded and the output falls below normal

Clinical features. Unlike mitral stenosis, aortic incompetence develops during the stage of active valvulitis, and may be at once permanent Its early diagnosis depends entirely upon recognising an aortic diastolic murmur, heard best down the left border of the sternum, and closely resembling the sound of a whispered "R" (Hope, 1839) In contrast to the mitral

diastolic murmur, there is no gap between it and the second heart sound, the one passing imperceptibly into the other. Thus the usual two-beat metre of the heart sounds is not altered (fig 9.16). In distinguishing aortic from mitral diastolic murmurs, the greatest stress is laid on this difference in rhythm; for aortic murmurs may be heard best at the apex beat, and mitral murmurs towards the base. It has already been explained that owing to the appreciable period which must elapse between the closure of the aortic and the opening of the mitral valves, mitral diastolic murmurs give rise to a three-beat dactylic cardiac metre.

When incompetence is more pronounced, numerous changes in the heart

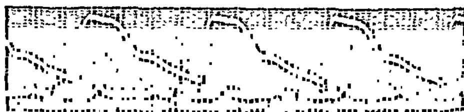


Fig 9 17—Arteriogram illustrating the water-hammer pulse of aortic incompetence The percussion wave is unusually abrupt, collapse precedes the pre-dicrotic notch, and is therefore a late systolic event

and circulation may be recognised. Owing to enlargement of the left ventricle, the apex beat is displaced downwards and to the left, and the cardiac impulse is heaving. At the mitral area a diastolic murmur may develop which has all the qualities of mitral origin there is a gap between its commencement and the second heart sound; it is soft, low pitched, and rumbling, it may be accentuated in presystole This is the Austin Flint murmur and may depend upon interference with mitral valve function by regurgitating blood, or upon left ventricular dilatation. It is indistinguishable from the diastolic murmur of mitral stenosis, but is rarely accompanied by a thrill.

During systole the increased volume of blood flung into the circulation raises the systolic pressure and distends the aorta and large arteries. The upstroke of the pulse wave is abrupt and of high amplitude (fig 9 17). When an artery is palpated, this sudden shock feels like a water-hammer (a Victorian toy consisting of a small quantity of fluid in a glass vacuum tube—Watson, 1843), and on auscultation the sound heard may resemble a pistol shot.

The abrupt distension and quick collapse of large arteries is well seen in the carotids, especially when the patient sits up. This characteristic visible

behaviour of an artery above heart level is Corrigan's sign (Corrigan, 1832)

On auscultating the femoral or other large artery, a systolic murmur is heard when the vessel is compressed, when a critical pressure is applied to the artery just distal to the stethoscope, a diastolic murmur may also develop. The latter was first described by Duroziez (1861), whose name is attached to the sign, and who attributed it to retrograde blood flow during diastole Duroziez's sign may occur, however, in any condition causing a



Fig 9 18—Skiagram showing prominence of the aortic arch and enlargement of the left ventricle in a case of aortic incompetence



Fig 9 19—Second oblique position showing enlargement of the left ventricle and unfolding of the aorta

large primary pulse wave, a steep predicrotic notch, and a conspicuous dicrotic wave Such an obstacle halts the blood flow at the pre-dicrotic notch, but is overcome by the dicrotic wave Above the obstacle the dicrotic wave is exaggerated, below it the dicrotic wave is flattened out Hence the diastolic murmur is heard above but not below the constriction The centrifugal direction of the passage of the wave which causes the murmur has been proved by means of simultaneous multiple phonoarteriograms (Luisada, 1943)

Vasodilatation exaggerates the collapsing quality of the pulse, further lowers the diastolic blood pressure, and causes capillary pulsation The latter may be demonstrated by lightly compressing a finger nail, by transilluminating the tip of the finger, or by pressing a glass slide against the lips Its presence depends upon direct transmission of the arterial pulse wave to the capillaries, and it occurs in any condition in which there is sufficient relaxation of the arterioles to allow this Thus capillary pulsation

may be seen in normal subjects after a hot bath, in thyrotoxicosis, arterio-venous aneurysm, fever, and in most hyperkinetic circulatory states. Pulsation of the retinal veins is another common finding

Skiagrams show enlargement of the left ventricle and prominence of the aorta. The ascending aorta pushes the superior vena cava further to the right, the aortic knob is accentuated, and the descending limb appears further to the left (fig. 9 18). Unfolding of the arch is seen better in the left

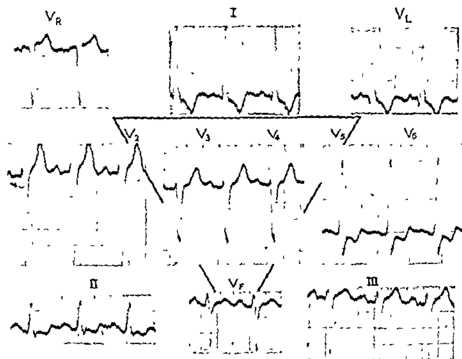


Fig 9 20—Electrocardiogram in a case of aortic incompetence showing evidence of left ventricular enlargement

anterior oblique position (fig 9.19). Fluoroscopy reveals exaggerated pulsation of the left ventricle and aorta Electrocardiography may provide additional evidence of left ventricular enlargement (fig. 9 20)

Most of the features described above are common to all forms of aortic incompetence, but their degree varies according to the etiology of the lesion. Aortic incompetence may be due to a congenital bicuspid valve, to rheumatic valvulitis (active or healed), to bacterial endocarditis, syphilitic

a rheumatic history, signs of associated aortic stenosis with or without calcification, the presence of other valve lesions, absence of angina pectoris, and by a normal erythrocyte sedimentation rate. It is not always easy to

be certain as to whether the mitral valve is stenosed when the chief lesion is obviously aortic incompetence, for then a mitral presystolic or diastolic murmur, backward displacement of the œsophagus, and widened bifid P waves may not have their usual significance The practical point emerges that a case presenting as one of aortic incompetence, with doubtful signs of mitral stenosis, is better judged rheumatic on other grounds

Course and prognosis The average life expectancy of rheumatic aortic incompetence is 20 to 30 years from its development. Prognosis should be based on the size of the left ventricle, and upon the degree of incompetence as judged by peripheral vascular behaviour. Effort tolerance often remains remarkably good until near the end. Failure is commonly with normal rhythm, and is usually left ventricular at first. Complications are practically limited to bacterial endocarditis.

4 *AORTIC STENOSIS*

Pathology. Fibrous scar tissue representing healed aortic valvulitis usually causes fusion of the cusps at their commissures. Slight narrowing at the aortic aperture is thus found in most cases of rheumatic aortic valve disease When fusion extends further up the margins of the cusps, true stenosis results. Valve leaflets become thick, rigid, distorted and often unrecognisable. Secondary valve calcification is common The aorta and large arteries often remain remarkably free from atheroma.

Effect on function. The aortic orifice must be reduced to about one-quarter of its natural size before changes in the circulation can be demonstrated (Wiggers, 1935). Left ventricular pressure curves then show a raised initial tension, steep isometric pressure gradient, and an elevated maximum pressure that is reached relatively early in systole, but there is no collapse as in aortic incompetence Pressure curves obtained from the aorta show an initial steep rise interrupted by an anacrotic notch and followed by a slower rise that reaches its maximum late in systole; the maximum pressure attained is less than normal The more severe the stenosis, the earlier the anacrotic notch The ejection phase is prolonged

To maintain the stroke volume and cardiac output great power must be developed by the left ventricle. The chamber is more hypertrophied and less dilated than in aortic incompetence. Again, the left ventricle must have sufficient time to perform its task it needs a long stroke and requires to be well filled in diastole.

Clinical features Aortic stenosis is at least twice as common in men as in women. The lesion may be discovered at any time from adolescence to old age, usually in the sixth decade Female patients tend to be younger than male.

Patients with aortic stenosis may complain of syncope (10 per cent), of angina pectoris (20 per cent), or of symptoms referable to left ventricular or congestive heart failure (Contratto and Levine, 1937) Syncope is of two kinds, cardiac and vasomotor. Cardiac syncope is abrupt and fleeting, and

may be due to paroxysmal ventricular fibrillation or possibly to locking of the valve (de Veer, 1938) Such attacks herald sudden death from a similar mechanism. The low blood pressure of aortic stenosis predisposes to vasomotor and to orthostatic syncope. Angina pectoris appears to depend upon poor coronary filling secondary to a jet effect or to the low mean aortic pressure; attacks are in no way different from those due to coronary atherosclerosis As usual, women with angina tend to be a decade older than the men

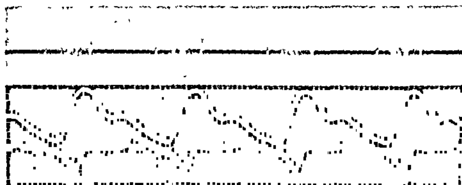


Fig 9 21—Arteriogram in a case of aortic stenosis The percussion wave is prolonged, and the maximum pressure is reached late in systole
(By courtesy of Drs Frances Gardner and Max Zoob)

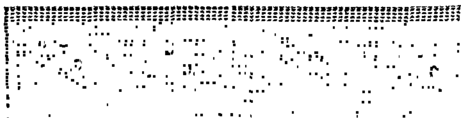


Fig 9 22—Arteriogram illustrating pulsus bisferiens in a case of combined aortic stenosis and incompetence P is the percussion wave, T the tidal wave, both are systolic events
(By courtesy of Drs Frances Gardner and Max Zoob)

The physical signs are as follows.

1. There is often a delicate pale pink complexion – the Dresden china look.

2. The pulse is characteristic when relatively slow (fig. 9 21), being small and sustained (plateau or slow-rising pulse). It depends upon the longer duration of left ventricular systole, the low blood pressure, and upon the delayed development of maximum aortic pressure These features tend to disappear as the heart rate quickens. When aortic incompetence is present as well, the pulse assumes a "bisferiens" quality (fig. 9.22). To the palpating finger it feels double, and may even be mistaken for coupling

percussion wave and its reflection from the periphery. Aortic incompetence increases the force of the percussion wave; aortic stenosis prolongs it Neither alone will produce this pulse.

3. The blood pressure is variable. In severe cases it is low, and the pulse pressure is small, but in mild or moderate cases, or when there is recognisable aortic incompetence, it may be elevated and the pulse pressure may be increased. About 10 per cent are truly hypertensive – an incidence a good deal lower than in controls of the same age-group.

4. The apex beat is displaced downwards and to the left, and the cardiac impulse is slow and heaving The left ventricle is hypertrophied rather than dilated.

5. A basal systolic thrill is usually present It is best appreciated when the patient leans forward and stops breathing in full expiration It may be most intense either to the right or to the left of the sternum A systolic thrill may also be felt over the carotid or subclavian arteries Although such a thrill is not diagnostic of aortic stenosis, it is suggestive and encourages prolonged search at the base



Fig 9 23—Skiagram of a case of aortic stenosis showing great enlargement of the left ventricle, slight prominence of the ascending aorta, and hilar congestion

6. A long, rough, basal systolic murmur is almost invariable. It is conducted into the cervical arteries, and may sometimes be heard remarkably well at the apex beat The second heart sound is usually soft or absent

7. On fluoroscopy, the left ventricle looks dense and bulky The aorta may be conspicuous, or relatively hypoplasic (fig 9 23) Calcification of the aortic valve can be seen in most cases, particularly if the patient is over 50.

8. The electrocardiogr
ventricular enlargement.
trophy and to the lack of
Standard leads then show the concordant pattern of left ventricular preponderance (fig. 9 24) Exceptionally high-voltage R waves are characteristic of aortic stenosis T is frequently inverted in leads facing the surface of

the left ventricle. Left bundle branch block occurs in about 15 per cent of cases, auricular fibrillation in about 5 per cent.

Differential diagnosis. If as much attention were paid to the quality of the peripheral pulse as to cardiac murmurs, aortic stenosis would be both less frequently overlooked and less often diagnosed in error. Functional basal systolic murmurs should not cause confusion. The murmur and thrill

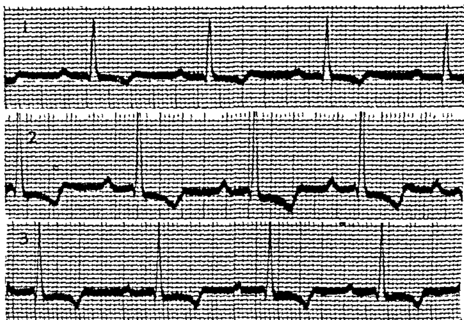


Fig 9 24—Electrocardiogram in a case of aortic stenosis showing concordant left ventricular preponderance in standard leads, the heart being vertical

of ventricular septal defect, though lower and more to the left, may be more difficult to distinguish, but the normal peripheral pulse, normal electrocardiogram, X-ray appearances, and absence of valve calcification help to prevent mistakes. Organic mitral incompetence may be recognised by the normal peripheral pulse and by the size and behaviour of the left auricle when viewed fluoroscopically The site of the maximum intensity of the murmur is less reliable evidence.

Etiological diagnosis is more difficult. Rheumatic aortic stenosis must be distinguished from congenital and calcific atherosclerotic varieties. In congenital sub-aortic stenosis, symptoms are absent, the heart is little enlarged, peripheral vascular findings are minimal, there is no aortic incompetence, and calcification is rare. Congenital valvular stenosis may be indistinguishable from the rheumatic variety, but the lesion is usually discovered in childhood, growth is retarded, the aorta may be hypoplasic, and incompetence does not occur.

It is uncertain whether calcific aortic stenosis in elderly or middle-aged

subjects is atherosclerotic or rheumatic. Thus eleven of twenty-one cases reported by Christian (1931) gave a history of rheumatic fever. Dry and Willius (1939) obtained a rheumatic history in 22 per cent of 228 cases, and Clawson, Noble and Lufkin (1938) found a rheumatic history in 35 per cent of 200 cases On the other hand, in the quoted series of Dry and Willius, there were 91 necropsied cases without disease of other valves, a rheumatic history was obtained in only four of these—the usual incidence in any series of normal controls. Again, in the quoted series of Clawson and his colleagues, 20 5 per cent of the patients were under 41 years of age, and 39 per cent were under 51, moreover, 89 had a mitral lesion as well It is obvious that many of these cases were rheumatic, but this has little bearing upon the question of whether or not pure calcific aortic stenosis in elderly people is rheumatic. On the pathological side, Clawson (1931) particularly has drawn attention to the frequency of inflammatory stigmata of the rheumatic type, but others, notably Soval and Gross (1936), have been unable to confirm such findings The best evidence of a rheumatic or other inflammatory etiology is perhaps the remarkable absence of atherosclerosis in the aorta and coronary arteries in most cases. All observers have agreed on this point that these vessels must have been long protected by the stenosis However, Monckeberg's original thesis that calcific aortic stenosis in elderly subjects may be degenerative (Monckeberg, 1904) has not been altogether disproved

Clinically, calcific aortic stenosis in elderly subjects behaves like rheumatic aortic stenosis

Course and prognosis At least 15 per cent of aortic stenotic subjects die abruptly, particularly if they have suffered from cardiac syncope or from angina pectoris About 10 per cent develop bacterial endocarditis. The majority who survive these risks succumb to congestive heart failure sooner or later

The prognosis should be based upon the behaviour of the peripheral pulse, upon the size of the left ventricle, and upon the nature of the symptoms When the pulse and left ventricle are relatively normal, the outlook is good, and life expectancy little curtailed Cardiac syncope and angina pectoris are serious, and give warning of sudden death at any time Between these two extremes all grades of severity are encountered Most cases, however, enjoy good effort tolerance until well into middle age

5 *TRICUSPID INCOMPETENCE*

Tricuspid incompetence may be functional or organic, the former being secondary to right ventricular dilatation with expansion of the tricuspid ring Clinical distinction is difficult in the first instance, but the course and response to digitalis and to rest may clarify the issue Functional incompetence may be temporary; organic tricuspid disease is always permanent

The diagnosis is based upon the following features

1 The cervical veins are engorged and pulsate with extraordinary

vigour. The quality of venous pulsation is altered: when there is auricular fibrillation, which is usual, a single prolonged venous pulse may replace the normal double movement; the *c* and *v* waves of the jugular phlebogram are more or less fused (fig. 9.25). The normal drop in venous pressure that follows the *c* wave is due to systolic descent of the base (floor of the auricles or atrio-ventricular septum), which produces a sucking effect. In tricuspid incompetence this negative pressure is replaced by partial transmission of the right ventricular systolic pressure to the right auricle (Bloomfield

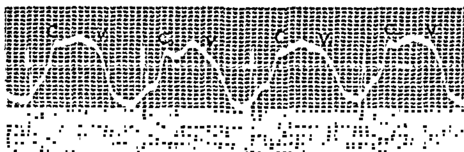


Fig 9 25—Jugular phlebogram showing fusion of the *c* and *v* waves in a case of tricuspid incompetence, owing to auricular fibrillation the *a* wave is absent.
(*By courtesy of Dr Max Zoob*)

et al., 1946) When there is normal rhythm the ventricular form of venous pulse may be preceded by a powerful *a* wave, the jugular pulse is then double, but the abnormal form may still be recognised at the bedside.

2 In long-standing cases a brownish pigmentation may be seen in the skin, especially of the head and neck.

3. Systolic expansile pulsation of a considerably enlarged liver can usually be recognised by palpation This must be distinguished from transmitted right ventricular pulsation

4. There is usually an early, long, blowing systolic murmur low down the left border of the sternum, and there may be an associated thrill. The murmur may increase in full inspiration

5 X-rays show gross dilatation of the right auricle, the border of which meets the diaphragm at a right angle, or even obtusely (fig. 9.26) In pericardial effusion this angle is usually acute. On fluoroscopy the right auricle occasionally expands in systole, and the right lobe of the diaphragm may reflect hepatic pulsation

6. Catheter studies have demonstrated reversal of the central venous pressure gradient during systole, forward flow being limited to diastole (Bloomfield *et al*, 1946) Venous valves take on the function of the tricuspid valve. The diagnosis of tricuspid incompetence may thus be proved by demonstrating a higher mean pressure in the right auricle and superior vena cava than in the subclavian vein (Sharpey-Schafer, 1947);



Fig 9 26—Skiagram showing gross dilatation of the right auricle with a blunt right cardio-phrenic angle in a case of tricuspid incompetence

moreover, as the catheter is withdrawn, pulsation ceases abruptly the moment the pressure falls (fig. 9.27).

The recognition of organic or permanent tricuspid incompetence is important, because patients so afflicted would otherwise be kept in bed indefinitely, in the belief that they suffered from congestive heart failure. Yet these patients may remain remarkably free from symptoms, and may be able to carry on their daily work for years, despite gross physical signs.

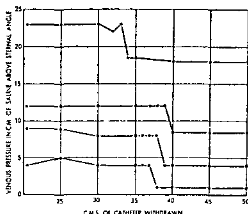


Fig 9 27—Graph illustrating fall in mean central venous pressure as the catheter is withdrawn from right auricle and superior vena cava into the subclavian vein

6 *TRICUSPID STENOSIS*

Although organic disease of the tricuspid valve is found at necropsy in 10 to 15 per cent of all cases of chronic rheumatic heart disease (Smith and Levine, 1942), clinical tricuspid stenosis is infrequently recognised It is nearly always accompanied by mitral stenosis (Pitt, 1909), often by aortic valve disease as well.

Tricuspid stenosis prevents proper cardiac filling, and in this respect resembles constrictive pericarditis (Thompson and Levine, 1937). Pulmonary congestion threatened by other valve lesions is thus prevented, attacks of dyspnœa and orthopnœa are noticeably absent; systemic venous engorgement, hepatic distension, ascites, and œdema, occur instead Tricuspid incompetence is usually associated

The diagnosis is based upon the following findings:

1. Engorgement of the cervical veins The characteristic finding is an abrupt and powerful *a* wave, which may be called a venous "Corrigan"; this does not alter with change of posture. It is, of course, only present in cases with normal rhythm.

2 Brownish discolouration of the skin, especially of the head and neck, as in tricuspid incompetence. Jaundice may also occur.

3. Considerable enlargement of the liver, sometimes progressing to "cardiac cirrhosis". The organ is unduly firm and is not tender Pulsation is presystolic when due to transmission of a giant *a* wave, or systolic if

It may be accompanied by a thrill As mitral stenosis is nearly always present, a separate tricuspid murmur easily escapes notice.

5. Gross dilatation of the right auricle seen on fluoroscopy.

6. Tall sharp P waves in the electrocardiogram in cases with normal rhythm (fig. 9 28). They represent right auricular hypertrophy. Owing to coincident mitral stenosis the P waves are usually widened as well. Auricular fibrillation, however, is often present

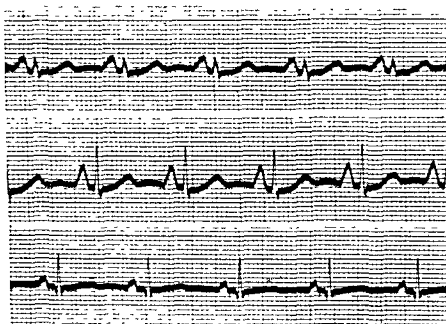


Fig 9 28—Electrocardiogram showing exceptionally tall P waves in a case of mitral and tricuspid stenosis

The most significant fact about tricuspid disease is that it gives rise to gross signs, suggesting severe right ventricular failure, in patients who are up and about and who may be practically free from symptoms, the discrepancy should at once draw attention to the diagnosis Life expectancy averages about five years from the time the diagnosis is first made (Aceves and Carral, 1947).

MYOCARDIAL FIBROSIS

The rheumatic process affects the heart muscle as well as the valves, leaving patchy myocardial fibrosis. Occasionally, cases of heart failure come to necropsy in which nothing but patchy fibrosis is found It is possible that some of these represent old rheumatic carditis Again, failure may occur in rheumatic heart disease when valvular scarring is insignificant. Permanent heart block or bundle branch block may be caused by fibrosis at the appropriate site.

ADHERENT PERICARDIUM

Pericarditis is one of the more innocent rheumatic lesions in respect to its after-effects Sometimes the two layers of the sac are fused and thickened; but this causes no trouble. Secondary calcification is rare, and scanty when present. Occasionally adhesions form between the pericardium and surrounding structures, so that the heart becomes anchored firmly in the mediastinum or to the thoracic wall The apex beat does not shift with change of posture, and Broadbent's sign is positive. Current opinion favours the view that this, too, is relatively innocent. Pick's disease, or chronic constrictive pericarditis, is very rarely, if ever, rheumatic. The matter is more fully discussed in Chapter XII.

TREATMENT

Competitive effort and hard physical work should be forbidden. Precautions should be taken against exposure to cold and infection. Patients are advised to train for a sedentary occupation, as a safeguard against progressive cardiac enlargement and future breakdown In mild cases moderate physical exertion may be allowed, but the patient must live well within the limits of effort tolerance.

No drugs, no particular diet and no special measures are required, except for complications, which must be treated as they arise, as described elsewhere Intercurrent pyogenic infections call for prompt chemotherapy. The problem of pregnancy is discussed elsewhere (page 507).

Modern surgery offers some hope for patients with tight mitral stenosis and severe pulmonary congestion. The most promising operation is mitral valvulotomy as performed by R. C. Brock (1950) Anastomosing a pulmonary vein to the azygos vein (D'Allaines *et al*, 1949) certainly relieves congestion in the lesser circulation, but presumably lowers the cardiac output and is unlikely to be so effective ultimately. The same may be said for the more hazardous procedure of tricuspid valvulotomy

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CHAPTER X

OTHER FORMS OF CARDITIS

THE HEART IN DIPHTHERIA

DIPHTHERIA may cause peripheral circulatory collapse, or toxic myocarditis Cutaneous diphtheria, so easily overlooked and so often untreated until too late, may be as lethal as the common faucial type. Early and adequate treatment with antitoxin has greatly reduced the incidence of toxic complications, but has by no means abolished them.

CIRCULATORY COLLAPSE

Towards the end of the first week or during the second week of the illness, the blood pressure may fall well below 100 mm. Hg; the patient becomes faint, sick, and restless, the skin pale, cold, and clammy; the pulse rapid and thready Loss of vasomotor tone may be due to toxic depression of the vasomotor centre, perhaps to peripheral sympathetic paresis, or possibly to poisoning of the vessels themselves. Occasionally it is brought about by suprarenal failure due to necrosis or hæmorrhage. The earlier the onset of circulatory collapse, the worse the prognosis Patients usually remain in a critical state for several days, in those who recover improvement may then occur, but the blood pressure usually remains low for two or three weeks.

The course of diphtheria may be complicated (as well as alleviated) by serum therapy, for this may induce not only immediate collapse from anaphylactic shock in a sensitised individual, but also later collapse from loss of plasma into the tissue spaces associated with serum sickness. Urticaria and œdema, usually on the ninth day, may be extreme, and result in a diminished blood volume and hæmoconcentration. Diphtheritic circulatory collapse and allergic "shock" may thus be expected at about the same time, and diagnostic difficulties may arise

Treatment of both conditions consists of absolute rest, adrenaline, 7 to 10 minims (0 4 to 0 6 ml.) subcutaneously, two- to four-hourly, and of raising the foot of the bed Sodium salicylate, 20 grains (1 3 G), two-hourly, and the antihistamine drugs are helpful in serum sickness The limbs may be bandaged with advantage in diphtheritic circulatory failure, and the cautious infusion of plasma is not irrational The prognosis is grave.

TOXIC MYOCARDITIS

Pathology. Diphtheritic carditis, being toxic in nature, may prove fatal without causing advanced changes in morbid histology The characteristic

finding is hyaline degeneration or necrosis of muscle, the fibres losing their striations and presenting a swollen granular appearance. Lesions are patchily distributed, and only short segments of individual muscle fibres may be affected. Monocytes cluster round the debris, and fibroblastic repair follows

Clinical features. Disturbances of rhythm tend to occur first, usually during the second week of the disease. Partial or complete heart block, and bundle branch block are the best known, and in patients who recover from the illness are usually, but not invariably, transient (Perry, 1939). Both heart block and bundle branch block commonly denote severe carditis, most such cases proving fatal (Burkhardt, Eggleston, and Smith, 1938). Ectopic beats are common, and although often innocent and unrelated to carditis, should be viewed with suspicion in diphtheria. Auricular fibrillation and paroxysmal tachycardia are rare. Ventricular fibrillation may be responsible for sudden death

Other evidence of carditis tends to occur a little later, usually during the third week Sinus tachycardia, gallop rhythm, enlargement of the heart and reduction of the pulse pressure are usual. The onset of heart failure may be suggested by pallor, breathlessness, præcordial oppression and vomiting Congestion is systemic rather than pulmonary, the jugular venous pressure being raised and the liver distended; there is rarely orthopnœa, paroxysmal cardiac dyspnœa, or pulmonary œdema. Significant murmurs and pericardial friction are absent.

The electrocardiogram is especially helpful in the diagnosis of diphtheritic carditis, much more so than in rheumatic carditis. Depression of the RS-T segment or primary inversion of the T wave in most leads is characteristic, and is found during the second week in the majority of cases which develop clinical carditis, and in some that do not. A similar pattern may be produced in cats within 48 hours by injecting diphtheritic toxin (Nathanson, 1928) Of 600 cases of diphtheric studied by Altshuler *et al.* (1948), 108 or 18 per cent developed these changes, while only 11 showed heart block.

Radiological studies on diphtheritic carditis are rare, because patients are not allowed to stand or sit, and should not be moved to the X-ray department. Portable skiagrams give little information about the size of the heart.

Prognosis. The outlook is grave, for sudden death is common, and presumably results from ventricular fibrillation or asystole Some patients die from congestive heart failure. Not infrequently, associated circulatory failure complicates the picture. Those who survive usually develop polyneuritis later, and this is apt to be severe. The total mortality rate is difficult to assess, for mild cases may well be overlooked, but it is usually put at 50 per cent.

If the patient survives, the ultimate prognosis is excellent (White *et al*, 1937), and complete recovery may be promised without reserve. It is

important that the patient should be convinced of this from the start, in order to prevent anxiety neurosis and to maintain good morale.

Treatment. Antitoxic serum will already have been administered in most cases, if not, it is too late to give it by the time cardiovascular symptoms develop. The axiom that antitoxin cannot do any harm and might as well be given even at this stage is untrue; for serum reactions are common and may prove fatal when there is toxic circulatory collapse or carditis.

Prophylactic treatment, in addition to early and adequate doses of antitoxin, consists of complete rest in bed for a minimum period of one month in all cases of diphtheria If by the end of this time there is no evidence of cardiovascular or neuro-intoxication, there is little further risk to life Should any such intoxication have occurred, however, bed rest must be extended for another month; otherwise sudden death may occur during convalescence in the second month Patients may be treated with far less respect subsequently, even when they have extensive polyneuritis.

The treatment of recognised carditis is unsatisfactory. Absolute rest is essential, for sudden slight effort, even sitting up in bed, may prove fatal during the critical period. Patients should be nursed flat, with one pillow, and should have everything done for them, including being fed and washed.

Diet should be light and fluids limited to two pints daily Digitalis is dangerous and should only be used in rare cases when auricular fibrillation with a rapid ventricular rate is associated with severe congestive heart failure Auricular fibrillation without failure is unlikely to last long if untreated, and is less dangerous than digitalis Diphtheritic heart failure with normal rhythm responds poorly to digitalis, and the drug is usually better withheld

THE HEART IN ACUTE INFECTIONS

Up to the beginning of the twentieth century it was generally believed that toxic carditis was a common complication of certain fevers, such as influenza It came to be recognised, however, that although "cloudy swelling" and "fatty degeneration" were often found at autopsy in cases dying from severe general infections, clinical evidence of cardiac involvement was rare The change of view followed the establishment of stricter criteria for diagnosing organic heart disease. palpitations and irregularities of the heart were shown to be due to autonomic disturbance or to innocent ectopic beats, systolic murmurs lost their previous significance, effort syndrome following infections was proved attributable to anxiety, X-rays failed to confirm clinical cardiac enlargement (based on the position of the apex beat), standard lead electrocardiograms were rarely abnormal The weight of negative evidence was considerable, and it became the custom to recognise no form of carditis other than that due to rheumatism or diphtheria In recent years, however, the earlier view has gained some support

Thus, Burch and Reaser (1947) considered infective or toxic carditis to be the most common cause of organic heart disease. Gore and Saphir (1947) found that diphtheria and rheumatism accounted for less than 25 per cent of fatal cases of myocarditis; they contended that carditis was common in a host of infectious and protozoal diseases, intoxications, and allergic states, including especially scrub typhus, bacterial endocarditis, meningococcal septicæmia, and sulphonamide allergy. At the same time an increasing number of cases of isolated myocarditis (Fiedler's) have been reported. It may be as well, therefore, to review the known facts critically; for there is grave danger that this modern swing-back may go too far.

FAILURE OF THE PERIPHERAL CIRCULATION

Cardiovascular disturbances in acute infections are commonly of two kinds, and neither is due to a cardiac fault. The first is peripheral circulatory failure This may be due to depression of the vasomotor centre, to toxic paresis of the vessels themselves, to suprarenal failure, or to diminution of the blood volume from dehydration or from loss of plasma into the tissue spaces through damaged vessels The essential mechanism is critical discrepancy between the effective vascular capacity and the blood volume, and the chief clinical feature is low blood pressure.

A good sign of vascular relaxation is a markedly dicrotic pulse, and although not necessarily serious, should put the physician on guard. Another significant feature is pallor and coldness of the extremities, due to vasoconstriction in the skin; this appears to be a compensatory mechanism helping to maintain the venous pressure and blood pressure when dangerous vasodilatation occurs elsewhere, e.g. in muscle Impending failure of compensatory vasoconstriction may be indicated by waxing and waning of the systolic blood pressure through a range of 10 to 20 mm. Hg A fourth indication of circulatory failure is mental confusion or faintness in the sitting posture Whilst tachycardia is the rule, and the half-hourly pulse chart of some value, it should be understood that deceleration sometimes accompanies a falling blood pressure, and that the character of the pulse is as important as its rate.

Circulatory failure should be treated by nursing the patient flat or with the foot of the bed raised, and by the intravenous administration of serum or plasma by the drip method, with or without 0.5 to 1 mg. of adrenaline to the bottle

The second common cardiovascular reaction to acute fevers is vasomotor neurosis during convalescence. This is discussed in Chapter XXI

TOXIC MYOCARDITIS

True toxic myocarditis does occur, however, especially perhaps in pneu-

theritic carditis, which it resembles. This histological picture is common to most forms of carditis—hence the difficulty in making an etiological diagnosis from autopsy findings. For example, 35 cases of sudden death following tonsillitis or common cold were reported by Gore and Saphir (1947), and ascribed to toxic myocarditis Thirty-one of them, however, could have been due to diphtheria or pneumonia, a negative throat swab does not exclude diphtheria.

Myocarditis and diffuse glomerulonephritis have long been known to complicate bacterial endocarditis; but when the death-rate of the septicæmic stage was 98 per cent, they received relatively little attention. Since the introduction of penicillin, however, heart failure from myocarditis has become chiefly responsible for the present 25 per cent mortality.

Histological examination of the heart in cases dying from meningococcal infection may disclose evidence of carditis; but clinical signs of cardiac involvement are most unusual, and the total mortality rate in adults is less than 1 per cent (Daniels *et al*, 1943) Whether meningitic or septicæmic in form, the infection responds particularly well to sulphonamides, and the rare occurrence of clinical carditis would probably be attributed to sulphonamide allergy.

Allergic forms of carditis, sometimes with peri-arteritis, giant cells, eosinophils, and nodules, have been described (Reinhart, 1946), sulphonamides provide an example of an antigen which may provoke such a response (French and Weller, 1942, French, 1946) Carditis, pericarditis and endocarditis may accompany acute disseminated lupus (Humphreys, 1948)

A most convincing type of protozoal carditis may accompany South American trypanosomiasis, or Chagas' disease (Chagas, 1909) Leishmanial forms of *T cruzi* multiply chiefly in the cells of the heart, brain and liver; the affected cells finally rupture and liberate the parasites into the blood stream An intense local inflammatory reaction follows The signs and symptoms of a typical acute or subacute carditis may dominate the clinical picture, and sudden death is common (Mosely and Miller, 1945).

Carditis accompanying scrub typhus (Tsutsugamushi fever) is less convincing Although histology may reveal myocardial damage and cellular infiltration in fatal cases (Corbett, 1943), the clinical course of the disease seems to be little influenced by them (Williams *et al*, 1944, Berry *et al*, 1945) In a series of 184 cases seen within one to four weeks after the acute symptoms had subsided, and 10 cases seen during the stage of fever, the electrocardiogram was virtually normal (Howell, 1945) For further information the reader is referred to the issue of the *American Journal of Hygiene*, May 1945, which is devoted to studies on scrub typhus

To assess the clinical value of the work of Gore and Saphir quoted above, it is worth noting that 16 per cent of their 1,402 cases of myocarditis were due to scrub typhus, and there was no evidence that myocarditis was the cause of death Their cases were highly selected, excluded children, and

were based entirely on autopsy findings: there were 227 examples of scrub typhus, 208 of bacterial endocarditis, 144 of diphtheria, 130 of rheumatic carditis, and 105 of sulphonamide allergy. The reader will draw his own conclusions.

Clinically significant carditis accompanying acute infections in Great Britain (other than rheumatic fever, diphtheria, and bacterial endocarditis) is undoubtedly rare. This applies as much to typhoid (Porter and Bloom, 1935) and influenza (Wood, 1941), as to the common exanthemata.

Clinical features of toxic myocarditis. In acute cases the signs and symptoms are similar to those of diphtheritic myocarditis, except that they may

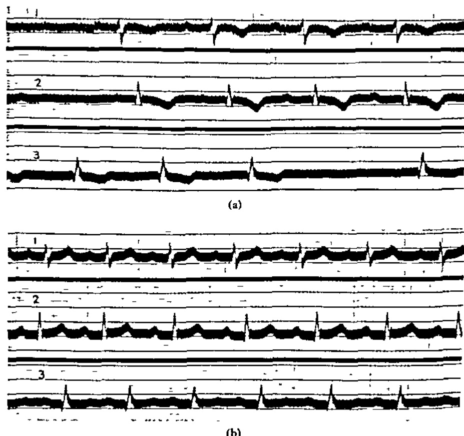


Fig 10 01—Electrocardiogram in a case of toxic myocarditis due to pneumonia. (a) Shows partial heart block with dropped beats and inversion of the T wave in all leads (b) After recovery.

occur earlier, during the febrile stage of the infection. Symptoms attributable to cardiac involvement may be absent; on the other hand, there may be dyspnœa, unexpected vomiting, pallor and peripheral cyanosis due to congestive failure, substernal oppression or discomfort, or palpitations

associated with changes of rhythm. It may be difficult to distinguish cardiac symptoms from those due to general toxæmia, particularly when there is peripheral circulatory failure. Sudden death is not infrequently the first tragic proof of myocarditis.

Physical signs include a small, rapid, thready pulse, low systolic blood pressure, small pulse pressure, gallop rhythm, dilatation of the heart, congestive heart failure, abnormalities of rhythm and electrocardiographic changes. The small rapid pulse and the low blood pressure may equally well be due to peripheral circulatory failure, and the gallop rhythm to fever (especially when there is anæmia) The size of the heart may be difficult to assess under the clinical circumstances, and the patient should not be moved to the X-ray department for more exact information The importance of recognising early signs of congestive heart failure will thus be appreciated. Abnormalities of rhythm are also important, and include all grades of heart block, auricular flutter or fibrillation, and paroxysmal tachycardia. The electrocardiogram is especially helpful, not only in establishing the nature of a rhythm change, but also in revealing partial heart block and abnormalities of the T wave (fig 10.01).

Sometimes the course of toxic myocarditis is subacute or chronic. The clinical features then closely resemble those of isolated (Fiedler's) myocarditis, described on page 318.

Prognosis. If the diagnosis is beyond doubt, the outlook is grave, the mortality rate probably approaching 50 per cent Whether central or peripheral in mechanism, the combination of hypotension and a small rapid pulse is always dangerous; and congestive heart failure often proves fatal. Abnormalities of rhythm and alterations of the T wave, without the manifestations just mentioned, are perhaps less serious

Many cases of mild toxic myocarditis must pass unrecognised; but this is not a matter for concern, for recovery appears to be complete in all non-fatal cases

Treatment Bed-rest and specific chemotherapy (when applicable) for all acute infections are axiomatic, bed-rest should be absolute if the cardiovascular system is involved The patient should be nursed in the position of maximum comfort; but if the blood pressure is below 100 mm Hg and there is no evidence of congestive failure, he should be kept horizontal, if there is congestive failure he should be propped up at 30 to 45 degrees against a back-rest. Digitalis should be avoided unless there is frank congestive failure, for it increases the risk of sudden death from ventricular fibrillation, and may aggravate minor degrees of heart block. If the venous pressure is well raised and the liver distended, however, it should not be withheld, and it may be invaluable in cases of auricular flutter or fibrillation. Mersalyl and a low sodium diet may be given if there is fluid retention Quinidine, 3 to 5 grains (0 2 to 0.3 G) t.d s., may prevent paroxysmal rhythm changes including ventricular fibrillation.

It must be admitted, however, that toxic myocarditis is little influenced

by therapy, and is apt to be fatal or otherwise according to its severity and irrespective of treatment. As in diphtheria, nearly all who recover, do so completely

ISOLATED MYOCARDITIS

Isolated myocarditis (Scott and Saphir, 1929) is a subacute inflammation of the heart of unknown etiology, characterised by patchy myocardial necrosis, cellular infiltration and fibroblastic repair, as in other forms of myocarditis. It was first properly described by Fiedler (1899). The disease may not be a specific entity and is difficult to distinguish pathologically from known forms of toxic or infective myocarditis of relatively long duration

Incidence Although still relatively rare, isolated myocarditis is being recognised with increasing frequency The majority of cases have occurred in subjects between the ages of 20 and 50, but infants, children, and old people are not exempt The disease has been reported sporadically in most countries and races, the only possible minor epidemic occurred in African troops serving in the Middle East (Bedford and Konstam, 1946), but neither the nature of the carditis nor its infective origin were certain: there were 40 cases with 17 deaths They may well have had a basis of malnutrition

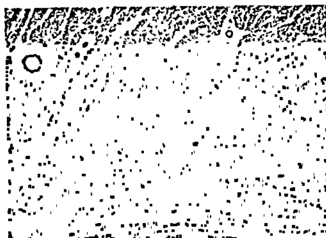
Pathology. Patchy necrosis of muscle is thought to be the primary lesion (fig. 10 02) Cellular reaction may be focal or more diffusely interstitial. Monocytes predominate, but in the acute stage polymorphs may be more numerous. Hæmorrhage and exudate may occur. Giant cells, eosinophils, and arteritis suggest another etiology—allergy Fibroblastic repair follows As a rule, all stages of activity and healing are seen in the same specimen; occasionally, extensive interstitial fibrosis is found alone, and is believed to represent the end-result of the same process

In some cases small brownish-yellow areas of gelatinous necrosis may be seen with the naked eye, particularly in the inner third of the myocardium The pericardium, endocardium and valves are not involved; but mural thrombi are common, and may give rise to emboli and infarcts in other organs

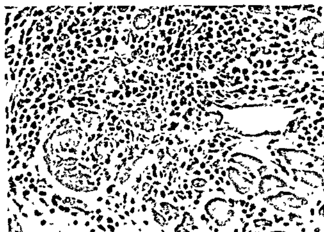
Clinical features. The history is invariably short, rarely longer than a few

onset (Josserand and Gallavardin, 1901; de la Chapelle and Graef, 1931)

The physical signs are usually those of congestive heart failure with a normal or low blood pressure, small pulse pressure, sinus tachycardia, peripheral cyanosis and pallor, cold extremities, general enlargement of the heart (fig. 10.03), gallop rhythm, and normal valves. The electrocardiogram often shows left bundle branch block. Angina decubitus may occur,



(a)



(b)

Fig 10 02—Focal necrosis in a case of Fiedler's carditis
(a) Low power
(b) High power The cells are macrophages, plasma cells, lymphocytes and eosinophils.

(*By courtesy of Dr C V Harrison*)

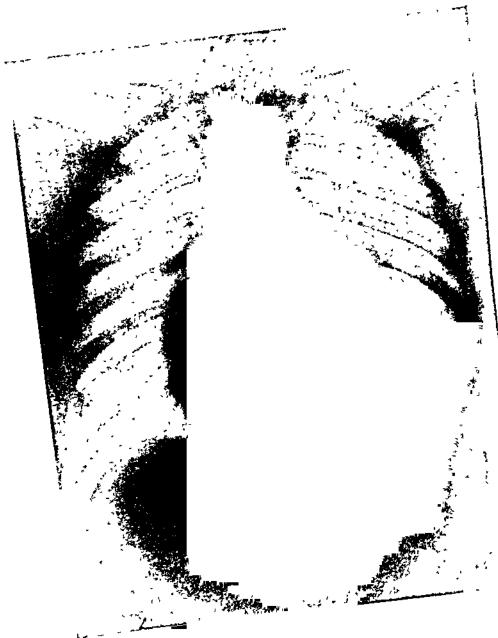


Fig 10 03—Skiagram showing general enlargement of the heart in a case of Fi
carditis

although the coronary arteries are healthy. In one such case Bayley (1946) recorded typical anoxic depression of the RS-T segment, and attributed it to the fact that the lesions were mainly close to the endocardium of both ventricles

Changes of rhythm are not unusual, and include paroxysmal tachycardia, auricular flutter or fibrillation, and partial or complete heart block. Ventricular fibrillation and sudden death may occur, as in diphtheritic and other forms of myocarditis. Embolic pulmonary infarction may result from dislodgment of right ventricular mural thrombi, or from phlebothrombosis in cases of congestive failure. Left ventricular mural thrombi may lead to embolism in the central nervous system, viscera, or limbs.

Differential diagnosis. The case usually presents as one of heart failure of uncertain etiology. It is at once distinguished from the hyperkinetic circulatory states (e.g. anæmia, beri-beri, arteriovenous aneurysm, Paget's disease of bone, thyrotoxicosis, anoxic pulmonary heart disease, uræmia, and certain diseases of the liver) by the obviously low cardiac output, but thyrotoxic heart failure with a low output may cause confusion. Myxœdema should be recognised by the slow heart rate and general features, the basal metabolic rate, electrocardiogram and blood cholesterol will resolve any doubts. Hypertensive pulmonary heart disease may be excluded by the skiagram and electrocardiogram. The heart is usually too large for Pick's disease, but pericardial effusion may be closely simulated: the apex beat is usually felt easily, however, is often forceful, and is obviously much displaced to the left, the pulse is not paradoxical and the blood pressure may not be low enough for cardiac tamponade. Gallop rhythm points to a myocardial fault The electrocardiogram may show left bundle branch block, partial heart block, or RS-T and T wave changes more in accordance with [illegible]

cases.

Rare forms of heart disease which may be confused with isolated myocarditis include congenital hypertrophy, familial cardiomegaly, von Gierke's disease, auricular myxoma, rhabdomyoma, secondary tumours, and, of course, other forms of myocarditis.

[illegible]

clinically closely resembles isolated myocarditis The endocardial fibrosis described by Davies (1948) may have a similar etiology

Course and prognosis All proven cases have naturally been fatal, even so, there have been no reports of probable or suspected cases which have survived Death has usually occurred within a few weeks of making the diagnosis or of admitting the patient to hospital

Treatment Absolute rest in bed, digitalis, mercurial diuretics, a low

sodium diet and venesection may help to diminish dyspnœa; but the general response is poor. Angina decubitus may be relieved by pethidine, 50 to 100 mg, or physeptone, 5 to 10 mg., four- to eight-hourly.

PYOGENIC CARDITIS

In addition to causing toxic myocarditis of the type previously described, pyogenic organisms may directly infect the heart. They may produce acute pericarditis with or without sterile or purulent effusion (Chapter XII), or may be responsible for acute bacterial endocarditis (Chapter XI) The staphylococcus, and occasionally the pneumococcus, may cause miliary abscesses in the heart muscle as part of a general pyæmia. Chemotherapy has greatly improved the prognosis of all forms of pyogenic carditis

MYOCARDITIS DUE TO DRUGS

Certain therapeutic drugs have earned the reputation of being dangerous to the heart, either by causing transient toxic myocarditis or by inducing ventricular fibrillation or asystole In the first group the best known are digitalis and emetine; in the second, choloroform, adrenaline, and potassium. Toxic myocarditis due to drug allergy is in a different category, and has already been discussed.

DIGITALIS

Digitalis is undoubtedly the best example of a therapeutic drug which may cause dangerous myocardial poisoning

Pathology. Buchner (1934) first demonstrated that necrotic myocardial lesions could be produced in animals (cats) by means of digitalis. Dearing, Barnes, and Essex (1943), also working on cats, produced focal necrosis, cellular reaction, and fibroblastic repair. Similar necrotic lesions may be provoked by acetylcholine and by continuous direct vagal stimulation (Banting and Hall, 1936, 1937), and have been ascribed to coronary constriction In the belief that the lesions due to digitalis were caused by the activity of acetylcholine, Kyser, Ginsberg and Gilbert (1946) succeeded in preventing them by the simultaneous administration of atropine or a coronary vasodilator, such as theophylline Whether digitalis intoxication in man is characterised by similar patchy myocardial necrosis, and whether this is mediated by vagal stimulation, remain to be proved, but it is a reasonable hypothesis

Clinical features. Anorexia, nausea or vomiting, and diarrhœa, usually give sufficient warning of digitalis overdosage, but there may be no such indication when carditis from other causes is already present. Disturbances of rhythm are common, and include coupling due to premature ectopic beats (fig. 10.04), nodal rhythm, partial or complete heart block (fig. 10 05), multiple ectopic beats, auricular fibrillation, paroxysmal tachycardia (fig. 10.06), and sudden death from ventricular fibrillation.

Fig 10 04—Electrocardiogram showing coupling from ventricular ectopic beats due to digitalis



Fig 10 05—Electrocardiogram showing partial heart block due to digitalis

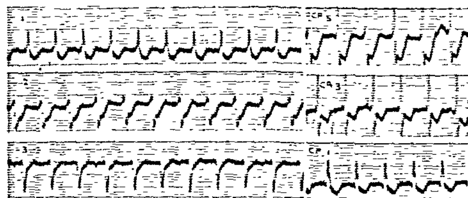


Fig. 10.06—Electrocardiogram showing paroxysmal tachycardia due to digitalis.

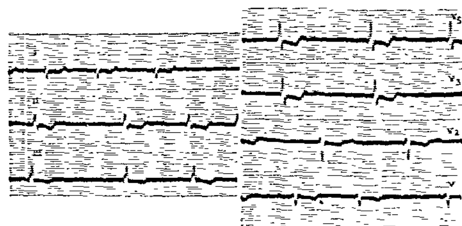


Fig. 10.07—Electrocardiogram showing depression of the RS-T segment due to digitalis.

The electrocardiogram shows characteristic sagging depression of the RS-T segment, maximum in leads V4-6 when there is normal or increased left ventricular dominance, or in leads V1-2 when there is right ventricular preponderance. The depression is transmitted chiefly to lead VL or VF

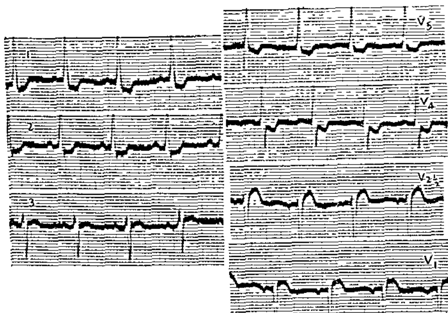


Fig 10 08—Shortening of the Q-T interval due to digitalis Q-Tc—0 3 sec

and thence to the appropriate standard lead according to the electrical position of the heart (fig 10 07). At first, the peak of T remains upright, but later becomes fused into a more sharply depressed RS-T segment, the Q-T interval being shortened (fig 10 08) The electrocardiogram offers by far the most reliable evidence of digitalis saturation, even when the patient denies having taken the drug.

Treatment The best remedy, apart from stopping digitalis, is atropine, but it is rarely necessary If the degree of intoxication appears dangerous, however, it may be given in doses of ½ mg two- to four-hourly for a day or two

EMETINE

Emetine is another therapeutic drug with a reputation for causing toxic myocarditis, the chief danger being abnormalities of rhythm, particularly ventricular fibrillation Emetine was used a great deal amongst British troops in the Mediterranean theatre during the second world war, but ill-effects on the heart were very rare if they occurred at all. Patients receiving emetine, however, were always confined to bed throughout the course.

OTHER DRUGS

Potassium, when used in large single doses (8 to 16 G) to stop paroxysmal tachycardia or multiple ectopic beats, or to differentiate between ischæmic and other causes of T wave inversion, is undoubtedly dangerous, and may cause sudden death from ventricular asystole, preceded by increasing heart block and bundle branch block (fig. 10 09). Spontaneous potassium poisoning may cause sudden death in uræmia.

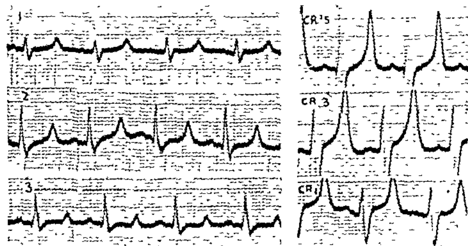


Fig 10 09—Widening of the QRS complex and accentuation of the T wave due to a high blood potassium in a case of uræmia The long Q-T is due to hypocalcæmia

Adrenaline in large doses may excite ectopic beats or almost any change of rhythm except heart block Transient hypertension and inversion of the T wave in leads V4-6 are common. Violent palpitations and substernal discomfort may occur, and patients with ischæmic heart disease usually develop a severe attack of angina pectoris Clinical examples may result from errors in the dose of adrenaline administered, or from spontaneous hyperadrenalism in cases of pheochromocytoma.

Chloroform is an example of a group of drugs, mostly anæsthetics, which may cause sudden death from ventricular fibrillation, especially in the presence of an excess of adrenaline.

Nicotine, as absorbed by heavy smokers, is capable of little more than provoking ectopic beats *Barium chloride* has a similar effect In a minority, smoking induces vasoconstriction and may adversely influence hypertension, ischæmic heart disease, and peripheral vascular disease, especially thrombo-angiitis obliterans. It also appears to aggravate thyrotoxicosis

Alcohol is a vasodilator, and in moderate amounts may benefit ischæmic heart disease; on the other hand, it may increase the work of the heart, especially if the blood volume is temporarily raised Heavy drinkers may

than they should. Otherwise, there is no evidence that alcohol has any effect upon the heart.

THE HEART IN ACUTE NEPHRITIS

Carditis accompanying acute nephritis (Whitehill *et al*, 1939) and toxæmia of pregnancy (Szekely and Snaith, 1947) is particularly interesting. The chief clinical features are elevation of the venous pressure, a tendency

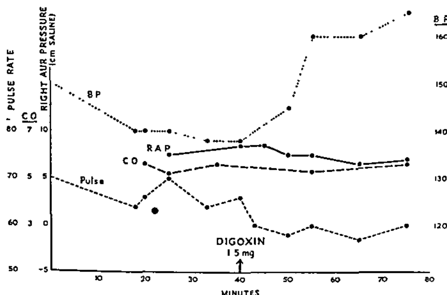


Fig 10 10—Graph illustrating a high right auricular pressure that does not respond to digitalis in a case of acute nephritis There is a conspicuous rise of blood pressure and slight slowing of the pulse, the cardiac output is unchanged

to develop acute pulmonary œdema, general enlargement of the heart, and inversion of the T wave in leads facing the surface of the left ventricle (Master, Jaffe, and Dack, 1937) The degree of hypertension is often insufficient to explain these findings Nephritic œdema is usually present and the blood volume may be raised

That there is some form of cardiopathy seems to be proved in certain cases by the behaviour of the cardiac output, which may fail to rise as expected when the venous pressure is high, on the other hand, the lack of response to digitalis (fig. 10 10) suggests that the heart is not usually overloaded. Histological examination of the heart muscle in fatal cases of acute nephritis presenting cardiac signs seldom reveals any structural abnormality, sometimes, however, the muscle fibres are dispersed by serous

exudate, lymphocytes and endothelial cells – even then there is little, if any, necrosis (Gore and Saphir, 1948).

It is probable, therefore, that the raised venous pressure is mainly due to an increased blood volume from retention of sodium and water or to some agent causing veno-constriction; and that, as a rule, the heart responds normally, but that in certain instances cardiac function is impaired, owing perhaps to biochemical rather than structural changes in the heart muscle, and that acute pulmonary œdema is a manifestation of left ventricular failure, even when the blood pressure is but little raised. The subject needs further investigation.

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CHAPTER XI

BACTERIAL ENDOCARDITIS

BACTERIAL or infective endocarditis means bacterial infection of any of the heart valves or of certain congenital anomalies of the heart or great vessels (bacterial endarteritis). It occurs in two main forms: acute (malignant), due to infection with any of the pyogenic bacteria; and subacute, due mainly to the *Streptococcus viridans*; but many other organisms have been isolated from both types. This broad classification is necessarily artificial, the course of the disease depending on the virulence of the organism and the resistance of the host. There is no clear division between the two types, and they are better considered as one disease.

There is usually some underlying fault, congenital or acquired The most susceptible congenital anomalies are pulmonary stenosis, bicuspid aortic valve, ventricular septal defect and patent ductus arteriosus; atrial septal defect is remarkably immune Any acquired valve lesion may become infected, including syphilitic aortic incompetence (Martin and Adams, 1938) and calcific aortic stenosis (Brink and Smith, 1937); but old rheumatic valvulitis is commonly to blame In quite a number, active rheumatic infection is still present when bacterial endocarditis is superimposed.

PATHOLOGY

The lesion is superficial and is not a valvulitis in the sense that rheumatic endocarditis is: bacteria invade the surface of a damaged or congenitally deformed valve, and are encouraged by the formation of small superficial thrombi which provide an excellent culture medium. Both in the natural disease and experimentally in dogs, there appears to be a paucity of granulation tissue and of cellular reaction; the microbes are not destroyed and healing does not take place Elsewhere in the body similar foci of bacteria are rapidly walled off by granulation tissue and the lesion is invaded by leucocytes the microbes are destroyed and the inflammation soon subsides (Friedman, Katz, Howell *et al.*, 1938)

The macroscopic appearances vary according to the infecting organism, tending to be finely granular with streptococcus viridans, ulcerative and hæmorrhagic with the hæmolytic streptococcus and pneumococcus, proliferative with the gonococcus. When associated with congenital defects, the site of the vegetations depends upon the direction of blood flow through the defect: thus, in the maladie de Roger vegetations are found on the right side of the patent interventricular septum, and on the wall of the right ventricle opposite the defect; with patent ductus arteriosus they are found

at the pulmonary artery end. Ulceration may lead to perforation of a valve cusp or sinus of Valsalva. In old rheumatic cases vegetations may spread on to the endocardium of the left auricle (Thayer, 1926).

The myocardium may show scattered focal lesions similar to those seen in isolated or toxic myocarditis, or small collections of lymphocytes, or lymphocytes and polymorphs, known as Bracht-Wachter bodies (Bracht and Wachter, 1909) The latter are believed to be embolic in origin and represent a local inflammatory reaction to bacterial nests (Perry, 1936). They are the non-suppurative counterpart of the miliary abscesses seen in staphylococcal cases.

OCCURRENCE

Bacterial endocarditis accounts for about 2 per cent of all cases of organic heart disease (White, 1937) It may occur at any age, but is most common in young adults. Males are affected rather more frequently than females Auricular fibrillation occurs in only 2 5 per cent of cases (McDonald, 1946), presumably because it is not a feature of the congenital lesions mentioned, is uncommon in rheumatic aortic valve disease, and occurs late in the life-history of patients with mitral stenosis There is no evidence that the two conditions are mutually antagonistic.

CLINICAL FEATURES

Patients may present themselves with cardiac symptoms, pyrexia of unknown origin, anæmia, a cerebral vascular lesion, subacute rheumatism, nephritis, broncho-pneumonia, or with other patterns which depend upon the nature of the invading organism, the underlying cardiac lesion, and the caprice of the disease process At the onset, symptoms are often ascribed to influenza, but fail to clear up The diagnosis rests upon the combination of a variety of signs which will be considered individually.

Cardiac abnormalities Evidence may be present of one or other of the various underlying valve lesions or congenital defects already mentioned, or there may be just an impressive systolic murmur at the mitral area, but if there are no abnormal auscultatory signs of heart disease, the diagnosis is rarely tenable. The development of a new valve lesion, or of the whining diastolic murmur and thrill of a perforated aortic cusp may be highly suggestive.

Toxic myocarditis is not uncommon and may cause heart failure and death whether the infection yields to treatment or not Its importance has been more widely recognised since the introduction of penicillin

Pyrexia Acute cases are always febrile, subacute cases are always febrile at some stage in the disease, but bouts of fever may alternate with afebrile periods The fever is irregular in type, usually low grade or moderate in degree, and may continue for weeks, months or years.

Anæmia Anæmia nearly always develops early, and is already present in

about three-quarters of the patients when first seen. It is indeterminate in type, being normocytic and isochromic, even when associated with hæmolytic infections. The red cells may be reduced to about three million and the hæmoglobin to about 60 per cent, giving a normal colour index. Stained films and bone marrow samples reveal no specific features. If microcytic hypochromic anæmia is found, the diagnosis should be doubted, for iron-deficiency anæmia itself may cause many of the signs and symptoms of bacterial endocarditis, e.g. functional systolic murmurs at the base or the apex of the heart, splenomegaly, petechiæ, red cells in the urine, and even low grade pyrexia

The white count is variable It may be normal; on the other hand there may be moderate leucocytosis or leucopenia Leucocytosis is usually associated with acute septicæmic cases, normal or leucopenic counts with subacute infections.

Splenomegaly The spleen is usually palpable It may be soft as in typhoid when due to septicæmia, it may enlarge rather suddenly as a result of splenic infarction, when it is tender; it may be firm in subacute cases; or it may be so large as to cross the mid-line in chronic cases

Petechiæ Petechiæ are common and sometimes appear in successive crops They may be seen under the nails, in the ocular fundi, in the conjunctivæ, or anywhere in the skin or mucous membranes Under the nails they resemble small splinters (Horder, 1926), in the fundi they may have white centres of exudate, in the skin they must be distinguished from minute telangiectases—Campbell de Morgan's spots Petechiæ, in successive crops or otherwise, are in no way diagnostic of bacterial endocarditis. They are due to capillary hæmorrhage and may occur in any condition in which the capillaries are suitably damaged, including most forms of sepcæmia, acute rheumatic fever (especially when associated with acute

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næmia.

by the capillary

resistance test.

A cuff is placed on the upper arm, inflated to a pressure of 50 mm of mercury, and maintained for five minutes; alternatively a pressure of 80 mm of mercury may be maintained for three minutes The arm below the cuff is then inspected. Most normal subjects are unaffected, but some develop a few tiny petechiæ in the ante-cubital fossa The result of the test may be expressed as slightly, moderately, considerably or grossly positive, or as negative, the four positive grades representing transitions from a few tiny hæmorrhages to gross purpura.

It may be positive or negative in bacterial endocartitis when spontaneous petechiæ are present When positive it is well to make sure that vitamin deficiency is not responsible, or to cover this possibility by giving adequate

Clubbing of the fingers (and toes) Clubbing occurs in about half of the subacute cases, but as it takes at least 3 to 6 weeks to develop, it is rare in malignant endocarditis. Early clubbing may be recognised by noting congestion and thickening of the nail-fold, and loss of the normal angulation between the nail-fold and the base of the nail. Slight clubbing should be interpreted with caution, however, for it may occur in many conditions including active rheumatic carditis. Conspicuous clubbing, on the other hand, provides excellent supportive evidence of bacterial endocarditis, if cyanotic congenital heart disease, pulmonary abscess, bronchogenic carcinoma, and a congenital origin can be excluded. The mechanism of clubbing is not yet fully understood

Nodes. Osler's nodes are small, transient, erythematous lesions about the size of a pea, lasting a few days, and vivid pink in colour when fresh, bluish when fading, often with a darker centre; they are raised, palpable, and tender, and may be found particularly on the pads of the fingers and toes, on the sides of the fingers, or on the thenar or hypothenar eminences (Osler, 1909). They are due to infected cutaneous emboli, and the responsible organism may sometimes be cultured from them

More important, perhaps, because more common, are larger deeper nodes which vary from the size of a pea to that of a grapefruit They are red, painful, hot and tender, may occur anywhere in the limbs, and may be mistaken for osteomyelitis or periostitis. When a lesion involves the finger it closely resembles an ordinary infected pulp; it is non-suppurative, however, and disappears in about a week if left alone Cultures from the inflamed tissue may yield *Streptococcus viridans* Red, tender macules are equally characteristic and even more common, and may also yield positive cultures from biopsies.

Emboli In addition to the minute emboli which cause white-centred petechiæ and the nodes just mentioned, larger emboli may block any artery —cerebral, visceral, or peripheral. They are more common in the radial, ulner, posterior tibial, and dorsal artery of the foot, than in the axillary or femoral artery, because their size is limited For this reason peripheral emboli are often symptomless and are only discovered by those who look for them. In cases of suspected bacterial endocarditis the peripheral vessels should always be palpated, and their patency noted for future reference.

Mycotic aneurysm Ulceration or degeneration of the wall of an artery due to local inflammation from an infected embolus lodging within the vessel or in its vasa vasorum may result in the formation of a small aneurysm In a peripheral vessel this is controllable, but when it occurs in a visceral artery fatal hæmorrhage from spontaneous rupture may ensue.

Pulmonary emboli. When bacterial endocarditis involves the pulmonary or tricuspid valve, or when it is associated with a left to right cardiac shunt, as in patent interventricular septum, emboli may be flung into the pulmonary circulation. Numerous small pulmonary infarcts result, and may

give rise to a clinical picture resembling recurrent or subacute hæmorrhagic bronchopneumonia.

Renal lesions. The various renal lesions that may occur in bacterial endocarditis represent almost every aspect of the disease.

(1) An embolus lodging in a small renal artery leads to simple infarction of the kidney, with hæmaturia, or without signs or symptoms.

(2) Minute bacterial emboli may cause embolic nephritis, which in greater or less degree is found in the majority of cases. Only some of the glomeruli are involved, rarely more than 60 per cent, and most of these have some of their capillary loops intact, so that the tuft is not entirely avascular, and the health of the tubules is not seriously threatened Affected capillaries are converted into a hyaline mass and red cells may be found in the capsular space and in the urine Embolic nephritis does not cause renal failure because a sufficient number of glomeruli are always spared (Baehr, 1921)

(3) In acute pyogenic forms of bacterial endocarditis, particularly when pneumococcal or staphylococcal in origin, miliary abscesses may be found in the substance of the kidney

(4) Petechiæ due to simple capillary hæmorrhage may occur on the surface of the kidney in the absence of embolic nephritis. They are then similar to those found in the pericardium, pleura and skin.

(5) Ordinary acute diffuse glomerulo-nephritis may occur as with other streptococcal infections, and may progress to renal failure; but not more than 5 to 10 per cent of all cases take this course.

(6) Simple congestion of the kidney may result from heart failure and give rise to albuminuria and to a few red cells in the urine.

It will be appreciated that these six types of renal lesion represent thrombotic emboli, benign bacterial emboli, septic emboli, simple hæmorrhage, toxæmia or allergy, and heart failure respectively, and that nearly all the features of bacterial endocarditis may be understood in terms of these six factors.

Changes in the ocular fundus. Simple petechiæ, like those in the skin, are fairly common. Occasionally, they have white centres, and may be embolic in origin It should be understood that these white centres represent exudate, and that identical lesions may be seen in other conditions, particularly leukæmia, pernicious anæmia, and malignant hypertension. The exudate may be surrounded by hæmorrhage or may be to one side of it. Embolism of the central artery of the retina or of one of its main branches may cause complete or partial loss of vision, but is fortunately rare Finally, papillœdema or papillitis, with or without widespread hæmorrhages and exudates, is not uncommon when there is diffuse glomerulo-nephritis, the appearances resembling those of malignant hypertension.

DIAGNOSIS

It is emphasised that pyrexia, anæmia, splenomegaly, petechiæ, and diffuse glomerulo-nephritis may occur wherever the site of the cardiac lesion, that systemic emboli, mycotic aneurysms, nodes, and embolic nephritis signify left-sided lesions, e.g. aortic or mitral valve disease, that multiple hæmorrhagic infarcts in the lungs are the prerogative of right-sided valve lesions and of left to right congenital shunts, such as patent ductus and maladie de Roger (Barker, 1949).

Clinically, bacterial endocarditis should be considered in all cases of unexplained fever with suspicious auscultatory signs in the heart If an indeterminate anæmia is also present, a determined search should be made for other evidence; if splenomegaly, petechiæ, and red cells in the urine are added the diagnosis becomes probable, but is still uncertain. On the other hand, clubbing of the fingers, nodes, peripheral emboli, mycotic aneurysm, nephritis, and characteristic fundal changes may, each one of them, be diagnostic of bacterial endocarditis when associated with fever and an appropriate cardiac lesion.

The diagnosis is confirmed by a positive blood or bone-marrow culture. Six tubes are usually set up from each sample; and 4 to 6 samples should be obtained at different times, preferably when the temperature is high, before a negative result is accepted. It should be pointed out, however, that blood cultures from patients with pyorrhœa or with dental abscess may grow *Streptococcus viridans* when the specimen is obtained after chewing, so that the diagnosis of bacterial endocarditis should never rest on a positive blood culture alone.

NATURAL COURSE

Untreated patients with acute infection die in a matter of days or weeks, usually from septicæmia or from the effects of embolism; those with subacute infection usually live for months and occasionally for years, bouts of fever with exacerbation of signs and symptoms alternating with afebrile quiescent phases, described by Libman as bacteria-free periods. Death may result from heart failure, cerebral or other visceral embolism, hæmorrhage, uræmia, or other causes. According to Libman and Friedberg (1941), about 3 per cent of all patients recover spontaneously, but Lichtman (1943) found that only 1 per cent of 2,596 cases collected from the literature so recovered.

PROGNOSIS

Penicillin and streptomycin have radically altered the course of bacterial endocarditis; for the infection can now be controlled in 90 per cent of cases However, about 35 per cent still die during or shortly after treatment, mostly from heart failure This high mortality may be due to the frequency of serious toxic myocarditis and to the relatively rapid increase in severity

of valve lesions. Uræmia accounted for only 6 per cent of the 131 deaths in the combined hospitals series reported by Christie (1948); emboli for 11 per cent and hæmorrhage for 8 per cent. The most important factors influencing the mortality rate proved to be the presence and degree of heart failure, the duration of the infection, and the nutritional state of the patient.

Relapses are common in inadequately treated cases, but should not exceed 10 per cent in patients who have received at least 0.5 mega unit of penicillin daily for a minimum period of 28 days. Nearly all those who relapse do so within one month of ceasing treatment. The frequency of recurrence (as distinct from relapse) is not yet known.

TREATMENT

Prophylactic. Surgical repair of patent ductus arteriosus not only cures the defect, but protects the patient from infective endarteritis Repair of coarctation of the aorta may be less successful in the second respect because infection may yet complicate an associated bicuspid aortic valve.

Dental hygiene is particularly important in all patients who have congenital heart disease or chronic valve disease. Tooth extractions, tonsillectomy, and other E.N.T operations should be covered by 100,000 units of penicillin six-hourly for 48 hours.

Acute pyogenic infections should be treated with penicillin rather than sulphonamides in patients who are susceptible to bacterial endocarditis

Chemotherapy. Sulphonamides have proved disappointing, and although they may temporarily sterilise the blood stream and lower the temperature, they rarely cure the disease Chemotherapy is at a disadvantage because bacterial endocarditis is practically avascular. As previously stated, bacteria are buried in a mass of thrombotic vegetations which serve as an excellent culture medium It is reasonable to suppose that if the formation of such thrombi could be prevented, the culture medium would become exhausted and the bacteria would starve or become exposed to chemotherapy. To effect this, heparin has been administered intravenously, either by the drip method or by four-hourly injection, over a period of weeks, the dosage being controlled by the clotting time of the blood which is kept at 30 to 60 minutes.

I tried this treatment for the first time in 1937 in an early case of bacterial endocarditis due to *Streptococcus viridans* on the mitral valve

The patient was a youngish woman in a good state of nutrition, who presented

venous injections at four-hourly intervals over a period of three weeks, and the clotting time was kept between half an hour and four hours. From time to time she bled rather profusely from her teeth, but there were no other ill-effects until the end. In addition to the heparin, a full course of sulphanilamide was adminis-

tered from the tenth day onwards. Two hours after the last dose of heparin, when her clotting time was still in the region of one hour, she died suddenly of subarachnoid hæmorrhage due, possibly, to a ruptured mycotic aneurysm. Owing to the prolonged clotting time she had no chance against this catastrophe At autopsy (when the blood was still unclotted) old vegetations were seen on the mitral valve, but there were no recent thrombi, the surface of the granulations being smooth and white Macroscopically the object of the treatment appeared to have been achieved Microscopically, however, numerous bacteria could be seen in the old thrombi, cultures from which were positive.

It was concluded from this experiment, which offered a peculiar opportunity for autopsy inspection at the critical moment, that three weeks' heparin treatment combined with sulphanilamide was ineffective. Subsequent work has confirmed this observation (Leach *et al.*, 1941).

Another method which it was hoped would yield more fruitful results was to combine chemotherapy with hyperthermia, for sulphonamides are more potent at higher temperatures in vitro (White and Parker, 1938); but this proved little better than heparin. Of a series of 489 cases treated with sulphonamides alone, collected by Lichtman (1943), 4 per cent recovered, of 109 cases treated with sulphonamides combined with heparin or hyperthermia, 6 4 per cent recovered.

The situation has greatly improved since the introduction of penicillin Patients should be treated early, as soon as the diagnosis is clinically probable, without waiting for positive results of blood cultures Every effort should be made to counter malnutrition, and a blood transfusion should be given if there is serious anæmia

The standard dose of penicillin is 0.5 mega unit daily, given in divided doses of 60,000 units three-hourly, 80,000 units four-hourly or 120,000 units six-hourly, and continued for twenty-eight days Nothing less than this will suffice, and larger doses prolonged for six to eight weeks are often necessary One of my patients was not controlled until she received a million units three-hourly and a total of 250 million units If the resistance of the organism is known, so much the better, but even then the optimum dose cannot be calculated exactly, because it depends partly on the physical properties of the lesion Swift and maintained clinical response is the only reliable criterion by which to judge the correct dose If, however, the resistance of the organism is known to be more than eight times that of the standard test strain of Oxford staphylococcus, the dose of penicillin should certainly be increased proportionately (Christie, 1948) If the coefficient of resistance is 10, not less than 100,000 units three-hourly will suffice, if 20, then at least 200,000 units three-hourly will be necessary—and so on (Baehr and Gerber, 1947) Peak (15 to 30 minutes after intramuscular injection) or constant (with the intravenous drip method) blood-serum levels of penicillin expressed in units per ml may also be measured, and checked against tables giving the expected level for the dose employed Peak levels should range from 2 to 25 units per ml with doses of 60,000 to

500,000 units intramuscularly; constant levels between 1 and 10 units per ml. with daily doses of 500,000 to 4 million units.

To avoid the discomfort of frequent needling, there is an increasing tendency to give massive doses of penicillin (0 25 to 0.5 mega unit) three or four times daily. As these massive doses have a penetrating power denied to more modest quantities, there is something to be said for this method, but they should not be given too infrequently.

Another way of reducing the frequency of injections while maintaining a sufficiently high blood level over the 24 hours is to give a suspension of procaine penicillin in oil (Herrell, Nichols and Heilman, 1947) ampoules are available containing 300,000 units per ml., injections are painless and may be given once daily Particular care should be exercised in using oily solutions on patients with right to left intracardiac shunts, owing to the danger of paradoxical cerebral embolism

Finally, the blood level of penicillin may be increased up to fourfold by the oral administration of certain substances such as benzoic acid (Bronfenbrenner and Favour, 1945), sodium benzoate, or caronamide (4^{1}/carboxy/phenylmethane sulphonanilide) which interfere with penicillin excretion by the renal tubules. The dose of each of these substances is 2–3 G. four-hourly (Boger *et al.*, 1948) Caronamide may be combined with sodium benzoate with some advantage and is a valuable adjunct to treatment in highly resistant cases.

Treatment of relapses or resistant cases. If the previous course of treatment was inadequate in dosage or duration, the standard 28-day course should be instituted, but if a relapse follows adequate treatment, every effort should be made to culture the organism and to determine its sensitivity to penicillin If its resistance is not greater than eight times the standard, the dose of penicillin should be doubled, and treatment should be continued for six weeks If the coefficient of resistance is greater than 8, the dose of penicillin should be increased proportionately. If the organism is highly resistant, or if it has not been isolated and the infection remains uncontrolled, streptomycin may be tried. The dose is 1 to 3 G. daily for four to six weeks Caronamide does not influence the blood level of streptomycin, for the latter is excreted by the glomeruli.

Toxic reactions of penicillin. Apart from local pain from subcutaneous or superficial intramuscular injections, and phlebothrombosis from intravenous injections, the only toxic manifestations which can be attributed to penicillin are fever and urticaria. Fever was common when crude penicillin was used, but is rarely seen nowadays Urticaria develops in about 5 per cent of cases and may be extreme, soft tissue œdema and hydrarthrosis are occasionally associated. This allergic reaction is alleviated by adrenaline and by the antihistamine group of drugs. Penicillin may be continued in mild cases, but may have to be stopped if the ction is severe

The chief toxic effect of streptomycin is on the vestibular ss of

the sense of balance may be permanent if heavy doses are continued after giddiness has developed. A conservative dose of 1 G. daily, however, may be continued in the presence of minor vestibular symptoms if the latter are controlled by means of antihistamine drugs.

Less toxic antibiotics, such as chloromycetin, are likely to replace streptomycin in the near future.

Other considerations. An infected ductus should be controlled by penicillin, then ligated as soon as the patient is fit enough.

Heart failure should be treated in the customary fashion, but the prognosis is grave in these cases

Diffuse glomerulo-nephritis may be mistaken for a relapse of bacterial endocarditis. If the renal function is impaired, the blood level of penicillin may rise considerably and thus aid the primary treatment, unfortunately, however, the nephritis usually proves fatal.

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CHAPTER XII

PERICARDITIS

THE features of pericarditis depend upon its etiology, upon the presence or absence of effusion, upon the nature and hydrostatic pressure of such effusion, and upon the development or otherwise of constriction in chronic or adhesive cases.

ETIOLOGY

Pericarditis may be rheumatic, tuberculous, pyogenic, traumatic, uræmic or secondary to myocardial infarction; malignant growths may invade the pericardium, hæmopericardium may result from rupture of a syphilitic or dissecting aneurysm, from perforation of a myocardial infarct or ventricular aneurysm, or from stab or gun-shot wounds of the heart, hydropericardium may complicate congestive heart failure or myxœdema; sometimes the etiology is obscure All these types have their own special characteristics which will be described subsequently, but they have also certain features in common.

DRY (FIBRINOUS) PERICARDITIS

All varieties of pericardial inflammation may present in this form The diagnosis rests on three cardinal signs. pain, pericardial friction, and a specific electrocardiographic pattern Disturbances of temperature, pulse rate, sedimentation rate, etc., of course, may occur, but are of little help in diagnosis

Pain. Capps (1932) found that the pericardium was insensitive to stimuli calculated to produce pain, except in that part of it, roughly its lower third, which is supplied by the phrenic nerve It follows that pericarditis should be painless unless the pain has phrenic distribution, or unless it is pleura in type from secondary involvement of that structure. In fact this is so in the majority of cases there is no pain; in some, pain is referred to the neck or shoulder tip; in others [illegible] the breath on in

Pericardia [illegible] the heart, according to the site and nature of the pathological process, but are most common at the left sternal border in the fourth intercostal space over the area of maximum cardiac dullness, where the pericardium lies in contact with the chest-wall. They are superficial, rough or smooth, loud or soft, their timing is peculiar, being out of step with the heart sounds Sometimes, they are confused with the to and fro murmur of aortic valve disease

or with artificial stethoscopic sounds; sometimes they escape detection. Pleuro-pericardial friction can usually be distinguished by its relationship to respiration.

Electrocardiographic changes. A diagnostic electrocardiographic T_2 pattern, first described by Porte and Pardee (1929), may be found in the majority of cases of genuine pericarditis, whatever the etiology, and whether

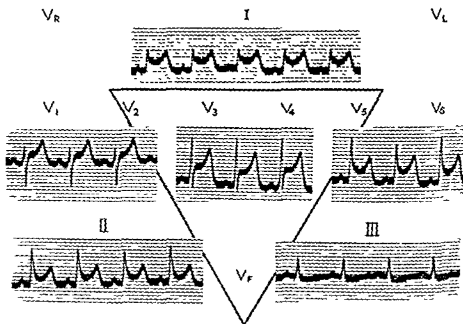


Fig 12.01—Electrocardiogram showing the early phase of the pericardial T2 pattern This graph is atypical in that the R-T segment is not elevated in lead 3

or not there is effusion (Wood, 1937). It develops in two stages, early and late, the changes usually appearing in all leads and therefore especially in lead 2. In the early phase (fig 12.01) the RS-T segment is elevated, but retains its natural concavity Within a few days it regains the iso-potential level or becomes depressed, and the T wave becomes flattened, diphasic, or inverted (fig 12 02), QRS remaining unchanged throughout or losing voltage. When the inflammation subsides the graph returns to normal, except when a tuberculous or pyogenic pericarditis merges into the chronic constrictive form, when flat or inverted T waves and low-voltage QRS complexes become permanent. The T_2 pattern may only be appreciated in serial electrocardiograms, as changes may be confined to leads 1 and 2 in

I

V_1 V_2 V_3 V_4 V_5 V_6

II V_F III

21ST JUNE 46

I

V_1 V_2 V_3 V_4 V_5 V_6

II V_F III

4TH JULY 46

Fig 12 02—Electrocardiogram showing later the phase of the pericardial T2 pattern. case of pyogenic pericarditis secondary to bronchopneumonia.

are recognisable structural changes (Kisch *et al.*, 1940) The early pattern of generalised pericarditis may be distinguished from that of myocardial infarction by the absence of a conspicuous Q wave, by the preservation of the upward concavity of the RS-T segment, and by the occurrence of maximum RS-T deviation in lead 2 (cf T_1 and T_3 types in myocardial infarction). When pericarditis is localised, however, changes may be maximum in leads 1 or 3 (Burchell, Barnes and Mann, 1939) The later stage

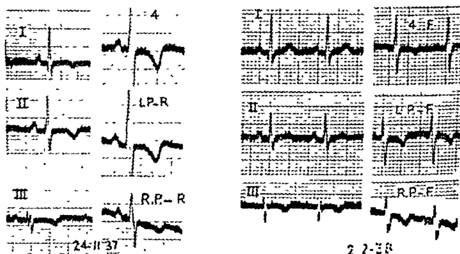


Fig 12 03—Electrocardiogram showing late changes due to pericarditis, in the second record (2nd February 1948) they are limited to the chest leads

may be confused with active carditis, myxœdema, carbon monoxide poisoning, severe anæmia, concordant left ventricular preponderance, combined anterior and posterior myocardial infarction, and long-standing congestive heart failure from any cause. On the other hand, the characteristic initial phase, the changing picture in serial graphs, and the clinical features of the case usually make the diagnosis easy.

PERICARDIAL EFFUSION

Fluid in the pericardial sac may be a simple transudate (hydropericardium), a straw-coloured sterile exudate, a purulent exudate, or blood (hæmopericardium) It may disturb the patient in one or more of four ways: (1) stretching of the pericardium may induce præcordial discomfort; (2) large effusions exerting pressure on surrounding structures, especially on the bronchi and lungs, may produce reflex cough and dyspnœa; (3) if the fluid is purulent, there may be constitutional effects similar to empyema, (4) as the pressure rises in the pericardial sac, cardiac filling is hampered, the pressure rises in the systemic veins, the ventricular stroke-output diminishes, and the blood pressure tends to fall The raised venous

pressure is partly beneficial, for it aids cardiac filling, the diminished stroke-volume is countered by tachycardia; vasoconstriction serves to maintain the blood pressure (Stewart, Crane and Deitrich, 1938) When these compensatory adjustments fail to meet the circulatory demands, the situation becomes critical (cardiac tamponade)

Effusions in excess of 250 ml. may be detected by percussion Dullness may be elicited in the second left space when the patient lies flat, to the left of the apex beat when the latter can be located, in the xiphisternal angle, and to the right of the sternum in the 4th and 5th intercostal spaces (Rotch's sign, 1878)

Auscultation reveals pericardial friction in the majority of instances, even with gross effusions, and the heart sounds are faint Signs of pulmonary collapse are common at the left base (Ewart's sign, 1896), and consist of dullness to percussion, increased tactile fremitus, bronchial breathing, and whispering pectoriloquy, with no adventitious sounds

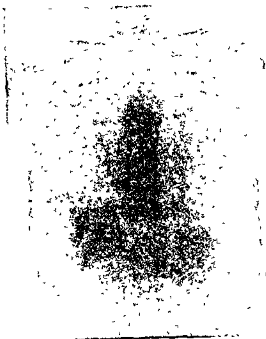


Fig 12 04—Skiagram of a case of pericardial effusion, showing an acute right cardiophrenic angle

Fluoroscopy shows the natural contours of the heart to be obliterated by a large globular or pear-shaped shadow which may change its shape with alteration of posture The right border usually meets the diaphragm at an acute angle (fig. 12 04), in contrast to the blunt right cardiophrenic angle of tricuspid valve disease (fig. 12 06). Pulsation is diminished and may be absent The size of the shadow may change rapidly and grossly from week to week (figs 12 04 and 12.05) In the first oblique position, the concave line of the inferior vena cava at the posterior inferior angle of the heart shadow is replaced by a convex backward bulge

Cardiac tamponade The pressure within the pericardial sac depends upon the quantity of fluid, the rate at which it accumulates, and the elasticity of the parietal pericardium The presence and degree of cardiac compression or tamponade may be assessed clinically by estimating the blood pressure, the venous pressure, the pulse rate and the amount of vasoconstriction.



Fig. 12 05—Skiagram showing rapid diminution in size of cardiac silhouette, as effusion is absorbed Taken six weeks after Fig 12 04



Fig 12 06—Skiagram showing the blunt right cardio-phrenic angle in tricuspid incompetence

Paracentesis is advised if the blood pressure falls below 90 mm. of mercury, or if there is a high venous pressure together with marked tachycardia and conspicuous vasoconstriction. The cervical veins pulsate less than in congestive heart failure, and considerably less than in tricuspid incompetence. Vasoconstriction results in pallor, cyanosis and coldness of the skin, especially of the extremities.

There is reason to believe that cardiac tamponade seriously interferes with the coronary blood flow, not only because the cardiac output is reduced and the blood pressure low, but because the pressure gradient between the aorta and coronary circulation is significantly reduced. The myocardium appears to suffer accordingly and true heart failure may result. This may explain those cases that fail to recover after decompression, and suggests that tamponade should be regarded as a medical emergency.

Differential diagnosis. It may be by no means easy to distinguish pericardial effusion from acute dilatation of the heart clinically or radiologically. The electrocardiogram may help, Q-Tc being relatively short in pericardial effusion and long when the heart is dilated. When the diagnosis is in doubt, however, it is best to explore with a needle, for the treatment of the two conditions is radically different.

Treatment. The object of treatment is to prevent death from cardiac tamponade, and is achieved by avoiding therapeutic agents which may lower the venous pressure, such as mersalyl, a low sodium diet and venesection, and by decompression if necessary. Paracentesis may be carried out to the left of the apex beat, or at any point where there is reason to believe there is plenty of fluid. If the needle touches the heart, forcible pulsation can be felt, and it should be withdrawn a little, or inserted elsewhere; with due care the risk of causing hæmopericardium from puncturing a coronary vessel is small. Fluid may also be removed if purulent or if untoward symptoms are caused by pressure on surrounding structures. Hæmopericardium, which is responsible for many cases of tamponade, requires surgical evacuation and repair of the underlying injury.

CHRONIC CONSTRICTIVE PERICARDITIS

Although Richard Lower described the paradoxical pulse and calcified pericardium as early as 1669, he was not in a position to grasp their full significance, and it was Chevers who really drew attention to the disease, giving an excellent account of it, with considerable understanding of the circulatory dynamics involved, in 1842. The term "Pick's disease" is un-

constrictive pericarditis.

Morbid anatomy. The condition may be regarded as a complication of the healing process following tuberculous, pyogenic, and perhaps certain other forms of pericarditis; for the fibrous tissue which may be

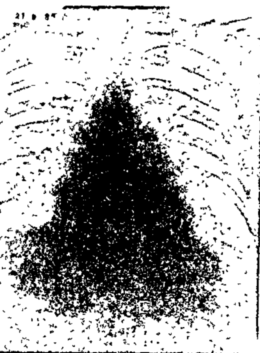
laid down so extensively in the active phase of these diseases contracts on maturation, and limits diastolic expansion of the heart Calcium is often deposited in large quantities, and the whole heart may become encased in "stone".

Etiology. Tuberculosis accounts for at least three-quarters of the cases, and may be still active when constriction first develops The pyogenic bacteria appear to be responsible for a few, and the cause is uncertain or unknown in the remainder. None are rheumatic (White, 1935)

Clinical features. The clinical picture is one of more or less generalised cardiac compression, the circulatory dynamics being somewhat similar to those of high pressure pericardial effusion The unyielding pericardium, however, sets a rigid limit to maximum cardiac filling, no matter how high the venous pressure, and the cardiac output can only be increased by acceleration of the pulse (Stewart and Heuer, 1939) Patients usually present themselves with dropsy and ascites, and may feel relatively well They may complain of breathlessness on exertion, but are usually comfortable at rest and able to lie flat. Examination reveals a high cervical venous column with diminished pulsation and, perhaps, inspiratory dilatation (Kussmaul's sign), enlargement of the liver, œdema, and ascites. Pulmonary congestion and orthopnœa occur occasionally. in these cases cardiac catheterisation may reveal a raised pressure in the pulmonary artery, proving that the constriction is mainly left-sided (Oglesby *et al.*, 1948) The pulse is small and often paradoxical, tending to disappear during inspiration, and the blood pressure is inclined to be low Compensatory vasoconstriction may give rise to pallor, cyanosis and coldness of the skin, especially of the extremities The heart itself does not appear to be enlarged. On palpation, there may be an appreciable diastolic shock, as if the heart, filling rapidly under the influence of a high venous pressure, suddenly met the unyielding resistance of a rigid pericardium, which, from a state of relaxation, was thrown abruptly into tension; on auscultation, this is represented by an accentuated third heart sound or early diastolic report Friction is absent Auricular fibrillation occurs in about one-third of cases, and is the rule in patients who are over 30 years old

Fluoroscopy reveals little cardiac pulsation, the heart shadow is normal in size in 45 per cent, slightly enlarged in 17 per cent, moderately enlarged in 32 per cent, and greatly so in 6 per cent, and has a relatively ill-defined outline (Oglesby, Castleman and White, 1948) Enlargement, when present, is usually due to the thickness of the pericardium which may measure as much as 26 mm (Freedman, 1939) The shape of the heart shadow is also altered, being triangular in half the cases, with straight left and right borders and a small or absent aortic knuckle. Calcification occurs in about half the cases, and is best seen in the left anterior oblique position (fig 12 07)

The electrocardiogram shows low-voltage QRS complexes, with flattening or slight inversion of T in all leads, representing the late stage



(a) Triangular-shaped heart



(b) Calcification seen in second oblique view.

Fig 12 07—Skiagrams of a case of constrictive pericarditis

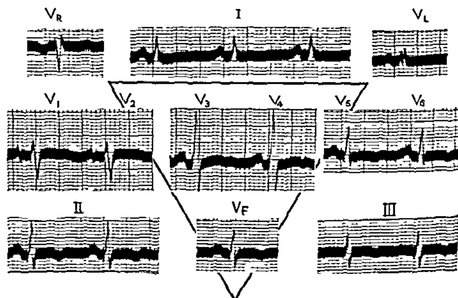


Fig. 12 08—Electrocardiogram in a case of chronic constrictive pericarditis showing low voltage and flat or inverted T waves

of the pericardial T_2 pattern, which in these cases is permanent (fig 12 05).

Treatment. Treatment consists of cardiac decompression, achieved by surgical removal of the constricting tissue (Churchill, 1929) The left side of the heart must be freed first, or acute pulmonary œdema may result Removal of calcium may be difficult and time-consuming, but is amply rewarded. The chief dangers during the operation are hæmorrhage and cardiac arrest or ventricular fibrillation The post-operative course has been smoother since the advent of chemotherapy, for pulmonary and pleural sepsis can now be avoided or treated effectively. The frequency of positive cultures obtained from pericardial tissue removed at operation has proved that activity is no direct bar to surgical treatment, but has encouraged the concomitant use of streptomycin. Dramatic clinical recovery may be expected after successful pericardiectomy, but the total operative mortality is about 33 per cent, and another 10 per cent of cases die shortly afterwards (Sellors, 1946) Persistent tuberculous activity is responsible for some of these deaths, and others have been due to inexperience In expert hands the immediate surgical mortality should not exceed 10 per cent in selected cases under 50 years of age; the risk in older patients is probably too great to justify operation Excellent results are obtained in 50 to 75 per cent, even though the venous pressure remains somewhat elevated and the electrocardiogram shows persistent inversion of the T waves

ADHERENT PERICARDIUM

During the first quarter of this century adherent pericardium was still considered an important complication of pericarditis Extensive adhesions anchoring the heart to adjacent resistant structures were believed to add a heavy burden to ventricular systole The theory was coloured by the pathological observations of Cabot (1926) who recorded gross cardiac enlargement associated with rheumatic adherent pericarditis The clinical picture [illegible]

of the ribs, fixation of the apex beat so that it failed to shift with change of posture, similar fixation of the electrical axis of the heart, and unexplained cardiac enlargement. To cure this unhappy condition, the operation of cardiolysis (Brauer, 1903) was devised to free the heart of its encumbrances by dividing adhesions between it and the surrounding tissues, and especially by extensive rib resection, so that the heart could pull against less resistant structures In more recent years, however, the serious consequences of adherent pericardium have been denied, and its surgical treatment is no longer favoured

Hosler and Williams (1936) failed to produce any cardiac enlargement or alteration of cardiac function by suturing the heart and pericardium to

the diaphragm in 13 dogs, nor could they find a single instance of cardiac enlargement in 76 cases of adherent pericarditis in which there was not an adequate organic intracardiac cause, chiefly valvular disease. Similar clinical and autopsy evidence was obtained by Armstrong (1940) in 72 cases and by Evans (Parkinson, 1936) in 49 cases.

All Cabot's cases of gross cardiac enlargement with adherent pericardium were complicated by serious valve disease. Although Broadbent's sign (if not confused with indrawing of the left antero-lateral aspect of the thorax, which may occur whenever the heart is grossly enlarged) and diastolic rebound of the ribs are reliable signs of extrapericardial adhesions, paradoxical pulse favours constriction, and fixation of the apex beat or of the electrical axis is too variable to be of diagnostic value (France, 1938).

TYPES OF PERICARDITIS BASED ON ETIOLOGY

Rheumatic pericarditis. The dry form may give rise to nothing more serious than transient pericardial friction, but it has an important bearing on diagnosis, its advent during the course of rheumatic fever proving beyond question the presence of active carditis. More extensive pericarditis is usually associated with gross rheumatic infection, so that serious carditis may be assumed These patients are often very ill, but it is not necessarily the pericarditis which makes them so The development of cardiac dilatation and failure, under these circumstances, is apt to be mistaken for pericardial effusion with cardiac compression, and indeed the differential diagnosis may not be easy. The position of the apex beat in relation to left border dullness, the ease with which it can be felt, and the presence or absence of dullness in the second left intercostal space, are good guides; but the electrocardiogram may be indeterminate, and the interpretation of portable X-ray films difficult (the patient being too ill to move to the X-ray department) Occasionally, diagnostic paracentesis may be necessary.

The electrocardiogram has failed to show any alteration of the S-T segment and T wave in at least half the cases of proved rheumatic pericarditis observed at Taplow, even when subsequent necropsy has revealed a grossly thickened pericardium. No other form of pericarditis behaves like this, and it is suggested that a superficial current of injury *may fail to develop because of the lack of an appreciable boundary* zone between the pericardium and underlying muscle owing to similar disease of both Shortening of Q-Tc, however, may occur, and in the absence of digitalis therapy at once distinguishes pericardial effusion from a dilated heart

Rheumatic pericardial effusion is a clear, straw-coloured, sterile exudate; it rarely compresses the heart, tends to be resorbed spontaneously without undue delay, appears to respond to salicylates and is usually best left alone.

Fortunately, there are no significant after-effects, for chronic constrictive pericarditis is practically never rheumatic, and adherent pericardium, though not uncommon, is of little importance. Pericardial calcification is seen occasionally, but is scanty and harmless

Treatment is limited to relief of pain, when present, and to cardiac decompression in rare cases of high-pressure effusion. For the former, antiphlogistine is comforting; but when the pain is severe morphine should be given. For the latter, paracentesis is required, and should be repeated when necessary. Salicylates may also help. Otherwise, treatment should be directed towards the rheumatic illness as a whole.

Tuberculous pericarditis. Tuberculous pericarditis may be uncommon, but it is hardly rare; it affects all age-groups, but favours coloured races and the male sex. The infection usually spreads from mediastinal lymph glands or pleura. Effusion is the rule, and if the patient survives, constriction may follow The onset is insidious, and in cases with effusion a large quantity of fluid may collect before symptoms are noticed Dyspnœa and an irritable dry cough, due to pressure on the lungs and bronchi, are the usual complaints. The absence of constitutional disturbances is often remarkable, but continued fever, anorexia, loss of weight, night sweats, and secondary anæmia may occur in the more active cases Diagnosis depends upon the absence of rheumatic manifestations, upon the subacute or chronic course of the malady, upon the discovery of tuberculosis elsewhere, and upon the results of culture and guinea-pig inoculation of specimens of fluid obtained by paracentesis. The effusion is usually a clear straw-coloured exudate containing lymphocytes, but is sometimes blood-stained. The course is prolonged, usually ranging between three and eighteen months, and is often downhill, with progressive emaciation, toxæmia, and anæmia, cardiac compression may become dangerous, when frequent tapping adds to the patient's misery

It is doubtful if more than 20 per cent of untreated cases with positive cultures survive, and of these the majority develop chronic constrictive pericarditis subsequently, not infrequently active and constrictive stages are telescoped. The prognosis is very different when tubercle bacilli cannot be recovered from the pericardial fluid, the mortality rate being then less than 10 per cent (Harvey and Whitehill, 1937), but of course the etiological diagnosis in many of these cases is open to question, and very few constrict later Streptomycin, 1 to 2 G daily for a month, is giving encouraging results, and may alter the outlook in proved cases

Polyserositis Whilst tuberculosis may affect the pleura and peritoneum as well as the pericardium, the term polyserositis (Concato's disease) is usually reserved for a somewhat similar inflammatory process of unknown origin Large effusions collect in the serous sacs, the fluid being a clear or opalescent, straw-coloured, sterile exudate. The process is obliterative, and in the pleural cavity paracentesis must be performed ever higher, as the two layers of pleura become fused together in a thick dense white matting Over the liver and spleen the greatly thickened peritoneum resembles a stout coating of sugar-ice. When the pericardium is involved, resorption of fluid is followed by total obliteration of the pericardial cavity, and constriction may ensue The course, prognosis and treatment are similar to those of tuberculous pericardial effusion

Malignant infiltration of the pericardium. When a male over 40 years of age complains of recent cough and breathlessness of insidious onset, and is found to have a large pericardial effusion, a malignant or tuberculous etiology is probable. If there is no fever and the fluid is blood-stained, the diagnostic scales tip sharply in favour of malignancy. When the pericardium is extensively invaded, hæmorrhagic effusion and cardiac tamponade are the rule, but when it is infiltrated by a single small nodule, the fluid is usually clear and straw-coloured, and the sac being more distensible, tamponade is less frequent. The condition is invariably fatal, and death never long delayed. Autopsy usually reveals a primary bronchial carcinoma.

Pyogenic pericarditis. Streptococcal, pneumococcal and staphylococcal infection may each give rise to pericarditis. Fever, leucocytosis and toxæmia are more conspicuous than in other forms. Effusion is common and usually purulent. It is generally believed that recovery may be followed by constriction, but the point is perhaps still uncertain. Streptococcal pericarditis may complicate tonsillitis, erysipelas, broncho-pneumonia, or any other streptococcal infection. It usually occurs during the acute stage of the illness, and is then readily distinguished from rheumatic pericarditis, but when there is an appreciable latent interval, this distinction is not so easy. Pneumococcal pericarditis is usually a complication of left basal pneumonia, organisms gaining access to the pericardium by direct spread from the pleura. Staphylococcal pericarditis may complicate myocardial abscess from staphylococcal septicæmia.

The course and prognosis of pyogenic pericarditis have been radically altered by chemotherapy. Penicillin is more effective than the sulphonamides, and should be given in doses of 30,000 units intramuscularly, every three hours day and night, for seven to ten days. About 10 to 20 ml. of a solution containing 1,000 units of penicillin per ml. should also be injected into the pericardial sac after paracentesis. Surgical drainage is only necessary when there is frank suppuration. With such treatment, initial recovery is the rule; but the ultimate outcome is uncertain. The low mortality rate may result in an increased incidence of chronic constrictive pericarditis; on the other hand, the prevention of frank suppuration may have the opposite effect. The few cases so far followed up by the author have not constricted

spontaneously. Effusion, when present, is sterile, and complete recovery takes place without treatment. Some of these are probably pyogenic in origin, and some are undoubtedly tuberculous, as the subsequent history may show. It is therefore wise to treat all such cases with penicillin or streptomycin, according to whether the clinical features correspond more closely to the pyogenic or tuberculous variety.

Hæmopericardium and traumatic pericarditis. Hæmorrhage into the pericardial sac may be caused by stab or gun-shot wounds, by rupture of a

syphilitic or dissecting aneurysm of the aorta, or by perforation of a myocardial infarct or ventricular aneurysm. Wounds of the heart are not necessarily fatal, and if the patient survives the initial insult, relief of cardiac tamponade and surgical repair may be life-saving. Rupture of the heart or aorta into the pericardium is always fatal, but not necessarily immediately. A patient with a perforated infarct, for example, may live as long as ten days

Severe blows or crush-injuries to the chest, or blast, may cause myocardial bruising and pericardial ecchymoses. Transient pericardial friction and characteristic electrocardiographic changes usually provide evidence of the lesion If there is no damage to the superficial coronary arteries, complete recovery is the rule

An interesting form of traumatic pericarditis may be due to pericardial foreign body (usually a metallic fragment) or to a foreign body lying close to the pericardium. In these cases recurrent attacks of pericarditis with clear sterile effusion may occur at any time up to four months after the original injury The interval between attacks is usually two to six weeks, during which the patient seems perfectly well The attacks themselves, which last about a week, tend to be severe, with fever, rapid effusion, cardiac tamponade, and considerable pain and distress Of seven cases reported by Wood (1945), however, none died. If the foreign body is easily accessible it is best removed in a quiescent period, if not, it may be safer to leave it *in situ*

Uræmic pericarditis Pericardial friction is not uncommonly heard in patients dying of uræmia Symptoms are rare, effusion absent, and electrocardiographic changes minimal At autopsy, needle-like crystals of urea may be found massed in the pericardium

Pericarditis secondary to myocardial infarction Acute myocardial infarction may give rise to a local (60 per cent) or general (15 per cent) pericardial reaction, and perforation may lead to hæmopericardium. Local pericarditis is limited to the surface area of the infarct, gives rise to no symptoms, and does not interfere with the electrocardiographic pattern of the underlying lesion. A fleeting friction rub may be heard if the infarct is anterior



Fig 12 09—Pericardial effusion of three years' duration in a case of extreme essential hypertension

Intra-pericardial pressure was 9 cm of saline and the venous pressure was raised The patient was able to lie flat or to be tilted head-down without breathlessness After paracentesis, orthopnœa and paroxysmal cardiac dyspnœa developed within a few days

General pericarditis is less

common but more important; for it may cause additional pain, allows anterior friction to be associated with posterior infarction (Stewart and Turner, 1938), influences the electrocardiographic pattern, and may even give rise to effusion.

Hydropericardium. Hydropericardium associated with congestive failure is never conspicuous and is of no clinical significance. As a complication of myxœdema pericardial effusion is not uncommon. An interesting though rare variety of hydropericardium is occasionally encountered in cases of malignant hypertension (fig. 12 09). Relatively high pressure may develop in the sac, and by hampering cardiac filling may prevent pulmonary congestion. Such cases may remain remarkably free from symptoms; if the effusion is tapped, orthopnœa and paroxysmal cardiac dyspnœa may develop

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CHAPTER XIII

SYPHILITIC AORTITIS

SYPHILITIC inflammation of the aorta is clinically unrecognisable unless it results in fusiform dilatation, saccular aneurysm, aortic incompetence, angina pectoris, or possibly heart block. It is true that many museums contain a specimen of syphilitic myocarditis, and even of syphilitic endocarditis, but these are oddities. The various manifestations of syphilitic aortitis commonly appear from ten to thirty years after primary infection, usually between the ages of 40 and 60, account for about 5 per cent of all cases of organic heart disease in Britain, and are approximately five times more common in men than in women.

There can be little doubt that the disease is becoming less frequent and will become rare. This is, of course, the result of educating the public in venereology, and in the improved treatment of early syphilis. Thompson, Comeau and White (1939) found cardiovascular syphilis had developed clinically in 10 per cent of 241 patients known to have had syphilis fifteen to twenty-five years previously, all had been inadequately treated by 1939 standards. Uncomplicated aortitis, rarely recognised except at necropsy, is undoubtedly much more frequent; but its exact incidence is difficult to assess, published figures depending on the criteria upon which the diagnosis rests. Aortic incompetence is about twice as common as aneurysm.

Whilst the clinical features may be diagnostic of a syphilitic etiology, the latter may be confirmed by a history of syphilis, by signs of syphilis in other systems (particularly neurosyphilis), by a positive Wassermann or Kahn reaction in the blood in about 85 per cent of cases, and by a persistently raised erythrocyte sedimentation rate.

Congenital syphilis does not cause aortitis (McCulloch, 1930); although spirochætes may be present in the aorta, there is practically no tissue reaction.

Pathology The initial lesion occurs in the adventitia, and consists of syphilitic endarteritis of the vasa vasorum and of focal granulomatous tissue. Although the inflammation spreads deeply into the media, atrophy and necrosis of muscular and elastic fibres are partly due to ischæmia. The damage is patchy and is repaired by fibrous tissue, the cross section of the aortic wall being correspondingly thinned at such points. These medial scars are indicated on the inner surface of the vessel by depressions of the intima, which presents a pock-marked appearance. Secondary atherosclerosis with extensive calcification is common.

ANEURYSM

Sooner or later the diseased media yields to the force of the blood pressure, either generally or at its weakest point, and a fusiform or saccular aneurysm results. A fusiform aneurysm is little more than an exaggeration of the inevitable dilatation of a syphilitic aorta, and has no greater consequences It is usually associated with aortic incompetence, but it may be seen radiologically when still uncomplicated, it then affords the only acceptable clinical evidence of relatively early syphilitic aortitis The diagnosis should be confirmed by a history of syphilis or by a positive Wassermann or Kahn reaction in the blood, however, for fusiform aneurysm may result from non-specific medial necrosis with or without dissection, and slight dilatation of the aorta may be due to atherosclerosis and hypertension A ringing or amphoric second heart sound at the base of the heart may denote dilatation of the ascending aorta, but does not indicate its cause Again, a suspicious aortic second sound must be disregarded if the ascending aorta is seen to be normal in size and shape.



Fig 13 01—Saccular aneurysm of the ascending aorta

The syphilitic aneurysm proper is saccular (fig 13 01), and may occur in any part of the thoracic aortic, particularly in the arch Aneurysm of the abdominal aorta is rare, and is more often atheromatous in origin

Incidence The sex incidence of saccular aneurysm is male to an even greater degree than other varieties of late syphilis, the sex ratio approaching 10 1 in their favour (White, 1937) This is probably due to the greater stresses imposed on the aorta in men It is significant that saccular aneurysm [illegible]

conditions which reduce the mean aortic pressure

ANEURYSM OF THE ASCENDING AORTA

Aneurysm of the ascending aorta usually causes visible pulsation or a conspicuous pulsating tumour to the right or left of the sternum or in the suprasternal notch Symptoms may be absent or there may be sternal or

costal pain from pressure erosion Pulsation may be expansile, and may be accompanied by a systolic thrill On auscultation, a loud systolic bruit is usually heard. When invisible an anterior aneurysm may yet be detected by percussing a band of parasternal dullness

Partial obstruction of the superior vena cava is a common complication, and gives rise to a high venous pressure in the head and neck, while the right auricular pressure remains normal The distended jugular veins do not pulsate, unless the obstruction is slight, and may be readily overlooked A visible collateral venous circulation does not necessarily develop, presumably because the block is incomplete, so that a fair blood flow is maintained under the high head of pressure. Puffiness or œdema of the head may occur, and in one case of the author's gravitated to the legs in the erect posture. The diagnosis may be proved by means of angiocardiography (fig 13.02) or by passing a venous catheter and noting the sudden fall in pressure as the tip slips through the obstruction.



Fig 13 02—Angiocardiogram showing partial superior vena cava obstruction due to an aneurysm
(*By courtesy of Dr Frances Gardner*)

Aneurysm of the ascending aorta may rupture into the pericardial or pleural cavities, into the pulmonary artery, or into the right auricle

ANEURYSM OF THE ARCH

[illegible]

position of the aneurysm Thus, pressure on one or other subclavian artery may lead to significant differences in the pulse and blood pressure in the two arms; a rare complication of this is clubbing of the fingers on the affected side. Pressure on the left bronchus causes collapse of the left lung, which may be complete or partial, the upper lobe being involved more often than the lower. Inflammatory changes may occur distal to the obstruction, particularly bronchiectasis and pulmonary tuberculosis The left bronchus may be depressed with each pulsation of the aneurysm; the resulting downward pull on the trachea during systole may be readily

detected at the cricoid cartilage, and is known as a tracheal tug It is best elicited by standing behind the patient, who should be seated, and applying steady upward pressure on the cricoid cartilage with the tip of one forefinger. Pressure on the trachea itself may give rise to an irritating cough, to stridor, or to considerable respiratory obstruction; pressure on the left recurrent laryngeal nerve to a brassy cough and paralysis of the left vocal chord, pressure on the œsophagus to dysphagia The phrenic nerve usually escapes as it lies superficially, but the left sympathetic chain may be compressed, with the production of Horner's syndrome· homolateral contraction of the pupil and partial ptosis. Severe radiating pains may be caused by pressure on nerve roots, and the spine may be eroded

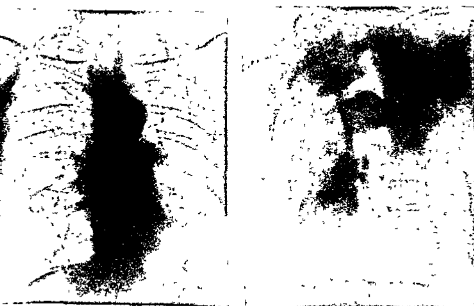
ANEURYSM OF THE ABDOMINAL AORTA

Of 1,459 aneurysms of the aorta collected from the literature by Ungar and Poppel (1936), only 136 or less than 10 per cent were below the diaphragm

An abdominal aneurysm usually presents as a pulsating tumour in the epigastrium, over which a systolic thrill and murmur may sometimes be detected. Root pain associated with vertebral erosion is not uncommon, or pain may be local. A relatively common clinical error is to mistake a normal aorta, projected forwards by lordosis in thin subjects, for an aneurysm

RADIOLOGICAL DIAGNOSIS

Although the existence and site of a syphilitic aneurysm may be diag-



(a) Antero-posterior view (b) Second oblique position

Fig 13 03—Skiagram showing several aneurysms of the aortic arch

(By courtesy of Sir John Parkinson)



Fig 13 04—Skiagram showing erosion of the bodies of several dorsal vertebræ as the result of pressure from an aneurysm



Fig 13 05 (a)



Fig 13 05 (b)



Fig 13 05 (c)

Fig 13 05—Angiocardiogram outlining a normal pulmonary artery (a), and aorta (b), in a case of mediastinal tumour (c)

nosed clinically with a fair degree of accuracy, radiological confirmation should always be obtained. Aneurysm may be distinguished from other rounded shadows in the vicinity of the aorta by having four characteristic features: (1) it is intimately connected with the aorta (fig. 13 03), (2) it becomes opaque with the aorta in angiocardiograms, (3) it pulsates, unless it is thrombosed; (4) some part of its wall may be calcified (fig 13.03a) Erosion of the bodies of several vertebræ (fig. 13.04), and compression of the trachea, bronchus or œsophagus may sometimes be seen. Confusion may arise, however, when a mediastinal tumour exhibits transmitted pulsation. Angiocardiography is advised in all doubtful cases (fig 13 05)

COURSE

Many aneurysms remain silent and are discovered accidentally by radiography, others cause much suffering. One of the worst features is the severe pain produced by pressure on bone, especially the root pain associated with vertebral erosion. This may last for months and be very resistant to treatment

The prognosis varies greatly, but the average duration of life is little more than eighteen months from the onset of symptoms (Colt, 1926–27). Cases have been reported, however, which have survived for fifteen to thirty years (Kauntze, 1947). The chief dangers are infection of the lungs distal to bronchial compression, and rupture. Aortic aneurysm may rupture into the pericardium, into the pulmonary artery, into the trachea or bronchus, into the œsophagus, or into the pleura, giving rise to hæmopericardium with cardiac compression, to acute right ventricular failure with signs and symptoms of an aorto-pulmonary shunt, to dramatic hæmoptysis, to hæmatemesis, or to hæmothorax, respectively, usually with fatal results

SPECIAL TREATMENT

The object of treatment apart from anti-syphilitic measures is to promote thrombosis and calcification in the aneurysmal sac, or to protect it by means of external fibrosis, in order to prevent rupture or further expansion

Bed rest is necessary at first while routine anti-syphilitic treatment is given (page 367). During this period a course of calcium lactate, 10 grains (0 6 G.) t.d s, with vitamin D may be added to promote calcification in the wall of the aneurysm.

If pain is not relieved by these measures, surgical interference may be considered. The old operation of inserting a wire into the sac in order to induce thrombosis is unsatisfactory: the risk is considerable and effective clotting cannot be guaranteed Babcock's operation—the creation of an arterio-venous communication between the carotid and jugular vessels (Babcock, 1926, 1932)—reduces the mean aortic pressure and may relieve

pain (Ranson, 1947). The most promising surgical method, however, is to wrap the aneurysm in polythene cellophane: this causes an intense fibroblastic reaction which protects the sac from without, prevents further expansion and relieves pain (Poppe, 1948).

AORTIC INCOMPETENCE

Pathology Weakening of the mesaorta in the region of the aortic valve leads to dilatation of the aortic ring, and to separation of the cusps at their commissures, so that the valve becomes incompetent. Granulomatous tissue may also drive a wedge between the junctions of the cusps. The cusps themselves become rolled and thickened at their free margins, and present a dwarfed stunted appearance. There is no stenosis, and calcification is absent unless there is much secondary atherosclerosis Owing to the site of the lesion, which is necessarily at the root of the aorta, the mouths of the coronary vessels are often scarred and narrowed; indeed they may be almost occluded. Ischæmic fibrosis of the myocardium results.

Incidence. Syphilis accounts for about one-third of all cases of aortic valve disease and for about one-half of those in subjects between the ages of 40 and 60 (Cowan and Ritchie, 1935)

The sex ratio in syphilitic aortic incompetence is about 3 . 1 in favour of men (Campbell, 1932), and is thus less remarkable than in aneurysm.

Clinical features Syphilitic aortic incompetence has all the features of aortic incompetence in general (page 295) and some special characteristics of its own Only the latter will be considered here.

1 The history of symptoms or of the discovery of the lesion is relatively recent, usually a matter of weeks or months and rarely more than a year or two

2. Angina pectoris is common, occurring sooner or later in about half the cases.

3. The aortic incompetence is pure, there being no stenosis (unless there is secondary atherosclerosis) and therefore no systolic thrill.

4 The incompetence is usually very free so that peripheral vascular manifestations are marked.

5. The murmur is apt to be "to and fro", replacing the heart sounds at the base, and is often heard better at the aortic area than down the left border of the sternum, owing to dilatation of the ascending aorta.

6. A basal diastolic thrill is suggestive, being very rare in other types of aortic valve disease except when a cusp is perforated or ruptured

7. Skiagrams may reveal differences in the diameter of the aorta at different points, or fusiform aneurysm (fig. 13 06); but an associated saccular aneurysm is rare. Irregularity of the lumen may be seen well in angiograms.

8 Fluoroscopy shows less aortic pulsation than in equivalent rheumatic cases, owing to the loss of elasticity.

9 Calcification of the aortic valve is against syphilis, but may occur when there is secondary atherosclerosis; calcification of the ascending aorta is in favour of syphilis

10. The electrocardiogram more often shows bundle branch block, or various degrees of heart block, than it does in rheumatic aortic incompetence; but no more so than in calcific aortic stenosis The changes are attributable to ischæmic fibrosis, rarely to gummatous lesions





(a) Antero-posterior view (b) Left anterior oblique position

Fig 13 06—Skiagram of a case of syphilitic aortic incompetence showing fusiform dilatation of the ascending aorta and gross enlargement of the left ventricle

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a

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reaction

Course The prognosis is bad, the average duration of life being about two years (Campbell, 1932) Left ventricular failure develops sooner or later in many cases, and congestive heart failure follows The downhill course differs from that of other forms of aortic incompetence in its rapidity, in the frequency of angina pectoris, and in the relatively high proportion of sudden deaths (Munck, 1946).

ANGINA PECTORIS

Pathology. It is often said that aortic valve disease may cause angina pectoris Whilst this is true, the statement needs amplification. Angina is a common complication of all forms of aortic stenosis and of *syphilitic* aortic incompetence, but not of other varieties. Rheumatic aortic incompetence, for example, must be gross to cause angina, and rarely does so. The explanation is to be found in the physiology of the coronary circulation. During systole, ventricular contraction prevents blood flowing through coronary vessels which penetrate left ventricular muscle, and large arteries on the surface dilate to form an elastic reservoir which in recoil during diastole acts as an accessory pump, forcing the blood onwards. The higher the systolic pressure, the greater the elastic reservoir, provided the coronary arteries are healthy. During ventricular relaxation blood is able to flow through vessels penetrating muscle, being propelled by the aortic diastolic pressure and by the recoil of the elastic reservoir just mentioned. Thus the coronary flow depends upon both systolic and diastolic pressures, i.e. upon the mean pressure.

Now in aortic stenosis the mean blood pressure is often low, but in aortic incompetence, although the diastolic pressure may be 40 or 50 mm. of mercury, the systolic pressure is commonly raised and the mean pressure adequate Syphilitic aortic incompetence causes angina pectoris because there is associated stenosis of the mouths of the coronary arteries. If syphilitic aortitis produces sufficient damage in the region of the aortic cusps to cause aortic incompetence, it is unusual for the mouths of the coronary vessels to remain unscathed Conversely, if the mouths of the coronary vessels are so stenosed as to cause angina pectoris, it is practically impossible for the root of the aorta to remain healthy. Thus syphilitic angina is rare without aortic incompetence

Clinical features Syphilitic angina has certain characteristics which help to distinguish it from other types: (1) the attacks tend to be of longer duration, (2) they are more often nocturnal, although the ordinary relationship to effort holds good, (3) they are less often relieved by trinitrin Coronary thrombosis is a rare complication because ischæmia is due to stenosis of the coronary ostia and not to changes in the coronary vessels themselves Myocardial infarction, however, may occur without coronary thrombosis, especially when the effect of gross occlusion of the mouths of the coronary vessels is exaggerated by a drop in blood pressure from some other cause, such as surgical shock. Ischæmia of the least nourished part of the myocardium may then be so pronounced as to cause necrosis: even so, cardiac infarction is uncommon

Course. The prognosis is bad, patients rarely living more than two years Status anginosus may develop before the end, or nocturnal angina may prove troublesome. When heart failure develops, angina may disappear; it is not clear why this should be so, but it may depend upon changes in tissue metabolism.

special care Bed rest is particularly important during the first six weeks of treatment, and is essential during the first course of penicillin or arsenic

HEART BLOCK

True syphilitic heart block is very rare, and depends upon interruption of the bundle of His by gummatous tissue On the other hand, heart block resulting from interference with the conducting tissue by ischæmic fibrosis, due to stenosis of the coronary ostia, is not uncommon, and like angina pectoris, and for the same reason, is nearly always associated with aortic incompetence. The former responds to iodine therapy, the latter, of course, does not

TREATMENT OF SYPHILITIC AORTITIS

Syphilitic aortitis should be fully treated with anti-syphilitic drugs, whether uncomplicated or otherwise. Clearly, past damage cannot be repaired, but further activity can be prevented. The objective is to secure a negative Wassermann reaction and a normal sedimentation rate

The patient should be put to bed for six weeks, during which period he should receive potassium iodide, 10 grains (0 6 G) t.d s , preferably with liq hydrarg. perchlor 60 minims (4 ml). Gummatous tissue resolves quickly with this treatment, and the danger of a severe Herxheimer reaction is lessened. After three to four weeks of treatment with iodides, a minimum of 2.4 million units of penicillin may be given over a period of 10 days in divided doses of 30,000 units three-hourly The course may well be modified in the light of experience, but the total dose should not be less. Reactions are rare, whether the initial dose is 1,000 or 100,000 units (Moore, 1947)

Shortly after completing the penicillin course the patient may be allowed up Iodide and mercury are then discontinued, and treatment with bismuth should be instituted Intramuscular injections of 0 1 G of bismostab twice weekly for six weeks, followed by 0 2 G weekly for the next six weeks are advised

The patient is then put back to bed, and arsenic is given intravenously, beginning with 0 15 G of N A B , and continuing with 0 3 G , 0 45 G , and 0 6 G , at weekly intervals, the last dose being repeated until a total of 4 5 G is reached If there is no untoward reaction after the first two 0 6 G doses of N A B., the patient may be allowed up again. The development or aggravation of angina pectoris or heart failure are major dangers, but both are unlikely, and when they do occur cannot always be attributed to the treatment. Nevertheless, arsenic should be abandoned should they occur.

The regime described constitutes one complete course of treatment, and lasts six months The situation should then be reviewed, particular attention being paid to the Wassermann reaction and the E.S.R. If both are normal, treatment may be discontinued for six months, but if either suggest persistent activity, the whole procedure, with certain modifications, should be repeated without delay Bed rest is no longer necessary, unless congestive failure, angina pectoris, or other complications demands it; and bismostab may be given in doses of 0 2 G , and N A B. in doses of 0 6 G., from the first injection

Two complete courses are strongly advised in all cases, with an interval of six months or consecutively. A third or fourth course should be given without hesitation if there is any further evidence of activity.

It is repeated for emphasis that neither aneurysm, angina pectoris, nor heart failure contraindicate penicillin or arsenicals, provided small doses are employed initially, for the Herxheimer reaction is rare. This phenomenon consists of a local tissue reaction which may cause swelling and occlusion of the coronary ostia, with disastrous results; even where there is no dramatic ill-effect, the patient may slip downhill with increasing angina or heart failure

Statistics have shown that the effect of full anti-syphilitic measures before the introduction of penicillin was to improve the average life expectancy from eighteen months to two years (Padget and Moore, 1935). It may be argued that the increased care and enforced rest which are a necessary corollary of this form of treatment might also improve the prognosis by a similar amount, and there is something to be said for the view that there is little point in attempting to extirpate the spirochæte once heart failure or angina pectoris has developed, for it is then probably too late. However, in the light of present knowledge, it is wiser to give full treatment to all cases Whether penicillin therapy will further increase life expectancy remains to be seen

Complications should be treated as they arise and by the customary methods. It is wise to avoid arsenic, and probably penicillin, in cases of heart failure or angina decubitus until these have been satisfactorily controlled

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CHAPTER XIV

ISCHÆMIC HEART DISEASE

DEFINITION

OCCLUSIVE disease of the coronary arteries of sufficient degree to prevent the coronary circulation meeting the physiological demands of the heart is best described as ischæmic heart disease. It is characterised clinically by angina pectoris and cardiac infarction; pathologically by occlusive coronary atherosclerosis, with or without thrombosis, and by focal ischæmic myocardial necrosis and fibrosis.

INCIDENCE

Occlusive coronary atherosclerosis is responsible for about 20 to 25 per cent of all types of organic heart disease, and for about 80 per cent of all sudden cardiac deaths (Munck, 1946), moreover, it appears to be increasing rapidly thus the number of cases dying from coronary disease in England per million persons living was 48 in 1926, 148 in 1930, and 473 in 1939 (Cassidy, 1946). The increasing age of the population is no doubt partly responsible, thus the citizens of ancient Rome in their halcyon days had an average life-span of twenty to thirty years, and the following table shows the increased average life-span in the U S A. from 1879 to 1944 (Master, 1947)

1879–1899 . .	34 years
1911–1912 . .	46 63 years
1919–1920 .	51.14 years
1930	57.36 years
1944 .	64.40 years

These remarkable figures are chiefly due to the successful war against infections and parasitic diseases, and to the saving of life by surgical means. Another factor that must be taken into account is the attitude of medical practitioners, who in 1926 had scarcely heard of coronary thrombosis, whereas now they are apt to diagnose it more frequently than it exists. It should be remembered that coronary thrombosis was not recognised as a clinical entity until its classic description by Herrick in 1912, and was not widely appreciated in England until popularised by McNee in 1925.

Sex. Of Heberden's 100 cases of angina, only three were women (Heberden, 1802). Most investigators give the general sex ratio as 4 : 1 in favour of men; but under the age of 50 it is 8 : 1 (Hedley, 1939), and under the age of 40 male predominance is overwhelming; in fact, angina in women under 40 is nearly always due to some other etiological agent such as hyper-

tension, aortic stenosis, syphilitic aortitis, anæmia, myxœdema, diabetes mellitus, xanthomatosis, or paroxysmal rhythm change. Between the ages of 60 and 70, however, about one-third of the cases are women, and over the age of 70 the sex incidence is equal (Gordon, Bland and White, 1939).

Age. Of 1,000 cases seen personally by Cassidy (1946), 70 per cent were between 50 and 70 years of age; of the men, 14.6 per cent were between 40 and 50, 3.2 per cent between 30 and 40, and 0 25 per cent were under 30 These figures are in harmony with common experience, except perhaps with regard to the incidence in young men; for many such cases were seen in the Services during the second world war (Newman, 1946, Poe, 1947). The peak age of death is 60 (Hedley, 1939).

Habits and occupation. There is a general impression that the incidence of ischæmic heart disease is particularly high amongst professional men and is related to the stress of modern urban life. There is said to be little to support this view (Master, 1947), but some figures published by Hedley (1939) are interesting

Occupation	*Deaths from coronary occlusion per 100,000*
Professional	154
Managers and officials . . .	140
Clerks and salesmen	128
Skilled and unskilled workers . .	107

The author, however, ascribed the difference in these figures to more accurate certification in those earning larger incomes

Nevertheless, the obstinate belief that angina pectoris is a doctor's disease persists, and has at last been justified by startling figures published by Ryle and Russell (1949) These workers, who are especially well qualified to sift and present evidence of the kind required, divided the social strata of England and Wales into five classes, and found that the standardised mortality ratio (S M.R) from ischæmic heart disease in social class I (professional workers) was twice that in social class III (skilled artisans) and three times that in class V (unskilled workers) Their table giving the actual occupations with the four highest and four lowest standard mortality ratios ends the debate on this previously vexed question and once again emphasises the fact that experienced opinion should not be too readily cast aside because of ill-founded statistical evidence to the contrary Physicians and surgeons head the list with an S M R. of 368, proprietors of wholesale business came second with an S M R of 235, the legal profession third (227), and the Church fourth (218). At the other extreme we have workers in chemical processes with an S M.R. of only 20, agricultural labourers 32, stone miners and quarriers 38, and coal miners engaged in other work 40

There is no evidence that either alcohol (Wilens, 1947) or tobacco (Cassidy, 1946) is responsible for the high male incidence or has any permanent influence on the course of the disease, although heavy drinking or smoking may provoke attacks of angina

PATHOGENESIS

Ischæmic heart disease is due to occlusive coronary atherosclerosis with or without secondary subintimal hæmorrhage or thrombosis Angina pectoris caused by *syphilitic aortitis, aortic stenosis, severe anæmia, paroxysmal*



Fig 14 01 (a)—Skiagram of the heart in a case of occlusive coronary atherosclerosis the coronary vessels have been injected with a radio-opaque gel.

tachycardia and the like, and coronary occlusion resulting from angiitis, embolism, trauma, dissecting aneurysm and other rarities are considered elsewhere.

The cause of human atheroma remains unknown, despite a great deal of

work on the subject (Cowdry, 1933) Lipoid substances accumulate in the intima of the aorta and larger arteries in a patchy irregular fashion, causing a variable degree of pressure atrophy of the underlying media, and sometimes encroaching on the lumen of the vessel (fig. 14.01)



Fig 14 01 (b)—Normal control for comparison

The lipoid nature of the deposits, their relatively frequent association with diabetes mellitus and hypercholesterolæmia, and their easy reproduction in rabbits by cholesterol feeding (Leary, 1934) suggest some relationship to fat metabolism The manner in which lipoid-laden macrophages (lipophages), swept to the side of the blood stream owing to their

light weight, may penetrate the intima has been recently described by Gordon (1947), hypertension facilitates the process.

The degree of narrowing of an atherosclerotic coronary artery cannot be accurately assessed by its appearance at necropsy, for in life the blood pressure tends to iron out the excrescences and maintain a smooth intimal surface and full lumen (Harrison and Wood, 1949).

Although the intima and early atheroma are avascular, advanced lesions develop a blood supply from the vasa vasorum (Leary, 1938), and subintimal hæmorrhage may then occur, causing sudden occlusion of the vessel (Paterson, 1936, 1939, 1941; Wartman, 1938), such accidents, however, are rare, and account for only about 1 per cent of cases of sudden coronary occlusion

Secondary calcification of advanced atherosclerosis may convert the coronary arteries into bony tubes, as in the classical example of John Hunter (1796). Erosion or ulceration of atheromatous lesions forms an excellent nidus for secondary thrombosis. This is the common cause of acute coronary obstruction Organisation of such thrombi leads to microscopical appearances similar to atherosclerotic lesions; indeed it has even been suggested that atheroma may represent nothing more than intravascular clotting (Duguid, 1946).

ANGINA PECTORIS

Physiology. Angina pectoris and its close relative, the pain of intermittent claudication, are believed to be due to certain metabolites that are formed in ischæmic working muscle (Lewis, 1934). Whatever the precise explanation for the development of pain there can be no doubt that attacks depend upon relative myocardial ischæmia, an idea first enunciated by Parry (1799) The term agina pectoris is customarily applied to transient pain only, and refers to ischæmic attacks provoked by temporary stress, during which the metabolic demands of the myocardium are beyond the capacity of the coronary circulation.

Such a situation may arise during effort (1) if the coronary vessels are more or less occluded either at their mouths, as in syphilitic aortitis (page 366), or during their course, as in atherosclerosis, various forms of angiitis, and embolism, (2) if the coronary flow is diminished by other means, such as aortic stenosis (page 300), gross aortic incompetence, or congenital anomaly; (3) if the blood itself carries insufficient available oxygen as in anæmia, or at high altitudes; or (4) if the regular work of the heart is increased by such conditions as hypertension, aortic valve disease, thyrotoxicosis or anæmia.

Although only angina pectoris resulting from coronary atherosclerosis concerns us here, the other factors mentioned often play a contributory role, thus anæmia may precipitate angina in a case of previously silent coronary disease, not only because of the limited oxygen supply, but also

because the work of the heart is increased in order to maintain a high cardiac output. Hypertension is particularly important in so far as it increases the work of the heart and contributes to the development of atheroma: on the other hand, it tends to iron out the plaques and so may prevent coronary narrowing; in fact most cases of hypertensive heart disease have dilated coronary arteries (fig 15.09) (Harrison and Wood, 1949). Clinically, although more than half of all cases of ischæmic heart disease have blood pressures above 160/100 mm Hg (Cassidy, 1946), systolic pressures over 200 mm Hg are rare (Riseman and Brown, 1937).

CLINICAL FEATURES

Angina is but a symptom, and may be distinguished from other pains in the upper half of the body by a careful analysis of its qualities and behaviour.

Site. The pain is central, mid-sternal, and tends to radiate bilaterally across or round the chest; into the sides of the neck and jaws, or even into the face or nose; into the shoulders and down the inner or outer sides of the arms, sometimes as far as the little fingers or thumbs; occasionally through to the back between the shoulder-blades (fig 14 02). This full distribution was experienced by John Hunter (1796). It is not situated in the left breast area, although it may be rather to the left of the sternum than in the mid-line, a localised left inframmary pain is never agina Radiation may be unilateral, and it is true that the left side then suffers more often than the right, but it must not be thought that spread down the left arm is either especially typical or diagnostic, for bilateral spread is more typical, and many other pains may radiate down the left arm, including left inframmary pain. Although centrifugal spread is the rule, radiation is occasionally centripetal, the pain starting in the wrists, upper arms, or face, and spreading thence to the chest. Pain may even be confined to one of the points of radiation, e g to the face, back, or wrist, not being felt in the front of the chest at all.

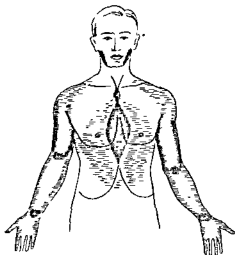


Fig 14 02—Diagram illustrating radiation of pain in ischæmic heart disease

Character. Angina pectoris is classically constricting, squeezing, pressing, or crushing; it is sometimes stinging, numbing, or burning, sometimes it

cannot be described adequately by the patient. It is not sharp, shooting or stabbing, which are the usual adjectives applied to left inframmary pain An important characteristic is its constancy, the pain being steady while it lasts, apart from initial waxing and final waning, no pain which is momentary, or which repeats itself in a succession of jabs or knife-like thrusts, is angina

Duration. Attacks are measured in minutes; usually they last two or three minutes, occasionally five or ten, they are not momentary, nor do they continue for hours, and any pain which behaves in either of these ways is not angina pectoris (as defined above)

Provocation Angina is characteristically produced by any effort that increases the metabolic demands of the myocardium beyond the capacity of the coronary circulation, and patients often know or learn the precise amount of effort necessary to provoke pain. When the critical point is reached the patient usually feels compelled to stop whatever he is doing, and to stand still until the pain passes off. Attacks are brought on especially by walking uphill, or against the wind, by hurrying after meals, or by any unaccustomed exercise, less so by manual work to which the subject is trained Pain may also be induced by emotion of a kind that raises the blood pressure or increases the cardiac output, but this is perhaps less typical, emotionally produced pain being more often innocent and associated with anxiety states In advanced cases, pain is provoked by lying down (angina decubitus) or stooping, tending to occur when the patient first gets into bed at night, or waking him from sleep. It may then depend upon the rise in cardiac output which follows change of posture from vertical to horizontal, or upon anxiety dreams

Pain that occurs after effort but not during it, or that is provoked by lying on the left side, or by the adoption of some particular posture (other than stooping or lying), is not angina, these features are characteristic of left inframmary pain

DIAGNOSIS OF ANGINA

If a pain conforms in site, quality, duration and relation to cardiac work, to the features mentioned above, it is angina pectoris, and the diagnosis must stand under any conditions except malingering. The diagnosis should stand likewise when pain conforms to the required features in three out of the four respects mentioned, provided it is not untenable in the fourth. For example, if a constricting pain, brought on only by exertion, and lasting but two or three minutes, is localised in the left inframmary area, it is not angina, for the site makes the diagnosis untenable, even though it conforms in the other three respects On the other hand, if the same pain is situated between the sternum and the left breast, it is almost certainly angina, because this site, though atypical, is not contradictory. Again, a midsternal pressing pain, brought on only by effort, but lasting fifteen minutes, is probably angina, for the long duration, though unusual, is not altogether conflicting; but should it last two hours, it is not angina as defined above

It is sometimes said that certain associated symptoms, such as breathlessness, dizziness or faintness, flushing, sweating, weakness, and a feeling of impending death, help to confirm the diagnosis. It cannot be stressed too strongly that these symptoms carry little weight, for they are vasomotor in origin, and although they may be provoked by an attack of angina, they are in no way characteristic of it, and are much commoner in the anxiety states.

tory distress

Anxiety states with left inframammary pain present no diagnostic difficulty; but when pain is parasternal, or even central, it may be very confusing The patients are usually women near the menopause, and they may describe a central pain radiating to the throat, jaws and arms, during or after effort, when reaching up to a high shelf, when washing or using their arms in other ways, and sometimes when emotionally upset As noted by Cassidy (1946), the attacks are apt to be widely spaced, unrestricted effort causing no distress between them Complete investigations may reveal nothing significant in any system, and the nature of the attacks remains obscure Angina can only be excluded, and then with some uncertainty, by obtaining a normal electrocardiogram during spontaneous or induced pain

Referred pain from the dorsal spinal ligaments may be felt across the front of the chest, as in the experimental work of Lewis and Kellgren (1939) Attacks may be related to posture or reproduced by spinal movements or pressure over the interspinous ligaments from D2–4

Œsophageal spasm may cause central chest pain radiating down both arms and tight or bursting in quality. There is no close relationship to effort, and bouts may be periodic like any other gut colic The diagnosis

Diaphragmatic hernia may cause pain on effort similar to angina pectoris, but it is usually more closely related to meals, and there may be associated

infarc-

being

Relief of pain by belching in any disorder of the œsophagus or stomach is less helpful in distinguishing such conditions from angina pectoris than might be supposed, for ischæmic pain may be similarly relieved in about 10 per cent of cases (Riseman and Brown, 1937)

Bronchial asthma or extreme dyspnœa from any cause may be associated with a feeling of substernal tightness that should not be confused with angina pectoris; for breathlessness is not a feature of transient myocardial ischæmia.

PHYSICAL EXAMINATION

Having made the diagnosis on historical grounds, the patient should be examined with a view to ascertaining the cause of the ischæmia. Aortic valve disease and severe anæmia should be recognised by their characteristic features, the presence of obesity or of hypertension noted, the mental state of the patient assessed, and attention should be paid to any other factor which may have any bearing on the frequency or severity of attacks. In this respect, diabetes mellitus and polycythæmia must be borne in mind. In the majority of cases, however, there are no physical signs: the rhythm is normal, the heart is not enlarged, there are no murmurs, and there is no evidence of congestive failure; the peripheral and fundal arteries and the blood pressure may provide no evidence of general vascular disease; fluoroscopy shows a heart shadow normal in size, shape and pulsation; and the electrocardiogram may be normal at rest. It is repeated for emphasis that this apparent normality of the cardiovascular system is typical of pure angina pectoris due to coronary atherosclerosis, and that with few exceptions, physical signs, radiological changes, or electrocardiographic abnormalities, are due to complications or associated disease; even the demonstration of peripheral atherosclerosis proves little, for it is common enough without serious involvement of the coronary vessels, and is often missing with advanced coronary disease.

SPECIAL TESTS

Most of the special tests are of little help, for the circulation is usually normal at rest. Effort tolerance tests based on the behaviour of the pulse rate and venous pressure are of no value. Reproduction of pain by prescribed effort for purposes of accurate analysis is sometimes useful with a bad witness, or pain may be induced to ascertain the prophylactic or curative effect of trinitrin. The only reliable test, however, is to obtain an electrocardiogram immediately after maximum effort, when characteristic depression of the RS-T segment, with or without inversion of the U wave, clinches the diagnosis (fig. 14.03). The best method is to make the patient exercise until he is in pain, if he stops on account of fatigue or breathlessness without developing pain, angina is unlikely, especially if the electrocardiogram remains normal. In the author's experience very few (less than 10 per cent) electrocardiograms remain normal during or immediately after an attack of true angina or after sufficient effort to cause breathlessness and fatigue (in ischæmic subjects). The other method is to take serial electrocardiograms while the patient breathes 10 per cent oxygen for twenty minutes, or for a shorter time if pain is produced. As depression of the RS-T segment occurs in normal subjects with this test, a positive result is only accepted if the depression exceeds 2 5 mm, in any lead or if the T wave becomes inverted in left ventricular surface leads or their counterparts (Levy *et al.*, 1938, 1939, 1941). The test is positive in 3 to 5 per cent of normal controls (Biorck, 1946;

(a) ANGINA PECTORIS: NO PAIN. AT REST.

(b) AFTER EFFORT NO PAIN

Weintraub and Bishop, 1947), in 15 to 20 per cent of cases of doubtful angina, and in 50 to 55 per cent of cases of undisputed angina (Levy *et al.*, 1941, Biorck, 1946) In the opinion of the writer this test is less useful than the effort test, being more difficult to carry out, more difficult to interpret, more dangerous, and far less frequently positive.

COURSE

The onset of angina pectoris is more often sudden than gradual, and is usually due to a small coronary thrombosis, insufficient to cause cardiac infarction The patient may say he was capable of climbing mountains a week ago, yet now he can scarcely walk 100 yards. Less commonly, pain is first experienced during unusually heavy exertion, and gradually becomes more easily provoked This represents the slow development of occlusive atherosclerosis.

The subsequent course is apt to be punctuated by short periods of relatively sudden deterioration, followed by long periods of gradual improvement these episodes signify thrombotic occlusion of a medium-sized coronary artery, followed by the development of a collateral circulation (Schlesinger, 1938), and perhaps by recanalisation

Sooner or later in the majority of cases thrombosis occludes one of the main coronary arteries, and cardiac infarction results; but a major thrombosis may occur without infarction, infarction may occur without thrombosis, and ventricular fibrillation may terminate the illness in the absence of both (Appelbaum and Nicolson, 1935; Nathanson, 1936).

Angina may cause total incapacity in really severe cases, and may finally occur at rest (status anginosus or acute coronary insufficiency).

Some cases, severe or otherwise, improve after cardiac infarction; others lose their pain on developing congestive heart failure It is not clear why this should be so, but the explanation may be related to the fact that ligation of the coronary vein appears to improve the coronary circulation (Beck and Mako, 1941).

PROGNOSIS

[illegible]

Sir Thomas Lewis, 1927–45. Women have a better prognosis than men, and subjects over 40 years of age at the onset fare better than those under [illegible]

gomery, Dry and Gage, 1947).

TREATMENT

Conservative. The majority of patients with uncomplicated angina of

mild or moderate severity are able to carry out sedentary or light manual work. Any mental or physical activity that increases the frequency of attacks or that causes pain directly should be avoided, whilst adequate rest and relaxation should be assured. Diet should be light and its fat content low, although hypercholesterolæmia is difficult to influence by such means.

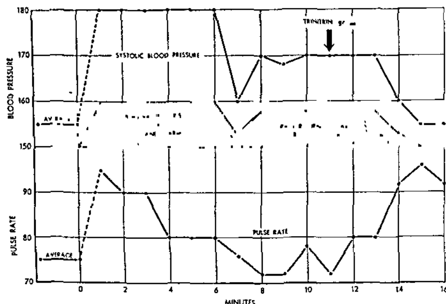


Fig 14 04—Graph showing close correlation between the height of the blood pressure and the degree or extent of pain during an attack of angina pectoris treated with trinitrin

Smoking should be given up if it is found to contribute to the frequency of attacks. Alcohol in moderation is not harmful, in fact, as a vasodilator it may be beneficial Contributory factors such as hypertension, obesity, anæmia, diabetes mellitus, and anxiety, should be corrected as far as possible

Trinitrin, 1/100 to 1/120 of a grain (0 5 mg), introduced by Murrell in 1879, may be carried and slipped under the tongue as required, either to relieve an attack or before some unavoidable effort which might induce one. Trinitrin is absorbed quickly through the oral mucosa, and acts as a coronary vasodilator relieving pain without necessarily altering the blood pressure (Wayne and Laplace, 1933–34), but if the blood pressure is lowered as well, so much the better (fig 14 04) Ischæmic S-T depression in the electrocardiogram is corrected quickly (fig 14.05)

Amyl nitrite, 5 minims (0.3 ml) is also effective but less convenient (fig 14 06): a capsule may be broken in a handkerchief and inhaled, the noise of the procedure, the pungent smell of the vapour, and the



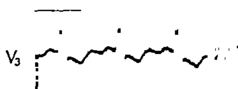












Fig 14 05—Graph illustrating rapid correction of ischæmic depression of the S-T segment in lead V3 in a patient with angina pectoris, by means of trinitrin

vivid facial flush that accompanies its use, are apt to embarrass the patient in public. Amyl nitrite is a powerful coronary dilator, for relief of pain is associated with considerable tachycardia and with conspicuous elevation of the cardiac output Much interest is also attached to the frequent paradoxical effect of amyl nitrite on the electrocardiogram; for the depression of the S-T segment that occurs during an attack of angina, and which is attributed to subendocardial myocardial ischæmia, often becomes further depressed when the drug is inhaled and pain passes off (fig. 14 07)

It is doubtful whether any of the drugs used as longer acting coronary vasodilators are of much value (Master, Jaffe and Dack, 1939) Aminophylline has the best reputation, and is employed widely in doses of 0.1 to 0 2 G t d.s. It is difficult to demonstrate a physiological effect with such doses, but severe angina may be relieved by 0 3 G four-hourly, if the patient can tolerate it. Epigastric pain and nausea usually prohibit larger doses

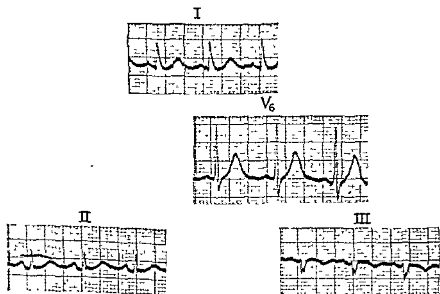
Recent reports have claimed that khellin, an extract from the seeds of an Eastern Mediterranean wild plant, *ammi visnaga*, is an effective coronary vasodilator with a prolonged action. The dose is 100 mg by mouth, three times daily. Angina pectoris is said to be relieved in 74 per cent of cases (Anrep *et al.*,

V_R I V_L

V_1 V_2 V_3 V_4 V_5 V_6

II V_F III

AT REST



AFTER AMYL NITRITE

Fig 14 06—Electrocardiogram during an attack of myocardial ischæmia treated with amyl nitrite.
Expected response showing prompt correction of the depressed S-T segment

have been envolved in recent years. Few have gained much support, but there is something to be said in favour of abolishing pain by means of sensory denervation of the heart achieved by means of section of the upper four dorsal spinal nerve roots, or by stellate and upper dorsal ganglionectomy (White, Garrey and Atkins, 1933) Destruction of the ganglia by means of alcoholic injection is less certain, and may cause intractable root pain in about 10 per cent of cases. Despite the theoretical argument that ganglionectomy may remove nature's warning signal, and so allow patients to exercise themselves beyond the limits of safety, there is no doubt that some cases do remarkably well (White and Bland, 1948). Sensory denervation of the heart does not entirely abolish the subjective recognition of an anginal attack, although the sensation experienced is not painful. There is good reason to believe also that sympathectomy tends to prevent ventricular fibrillation (Leriche *et al.*, 1931, McEachern, 1940), and seems to improve the coronary circulation either by preventing reflex spasm (Levy and Moore, 1941), or by causing coronary vasodilatation (Katz and Jochim, 1939)

A more drastic surgical procedure aims at improving the coronary circulation by supplying it with a new source of collateral vessels The idea was based on necropsy observations which showed that the heart might function remarkably well despite almost complete coronary occlusion, if for some reason an adequate collateral circulation had developed through the pericardium These natural results of accident and disease have been marshalled and developed by Claud Beck (1935–36) in the U S.A., and by O'Shaugnessy (1936–37) in England. Beck sutured a flap of pectoral muscle to the surface of the heart, O'Shaugnessy preferred cardio-omentopexy,' the omentum being brought up through the diaphragm and stitched or glued on to the surface of the heart after scarification Whilst experimental evidence affords convincing proof of the establishment of a collateral circulation by such means, the results obtained in clinical cases of ischæmic heart disease scarcely justify the risk entailed.

A simpler means of achieving the same object is to introduce bone dust into the pericardial sac; when the pericardial reaction subsides, vascular adhesions offer a collateral source of blood supply to the myocardium (King, 1941) This method deserves further trial

CARDIAC INFARCTION

Myocardial infarction occurs when a mass of heart muscle is sufficiently deprived of its blood supply for an adequate time. The common cause of such an event is coronary thrombosis; but coronary embolism, rupture of an atheromatous plaque, subintimal hæmorrhage in an atherosclerotic vessel, dissection, and critical lowering of the blood pressure, as from shock or hæmorrhage, in a patient with occlusive coronary atherosclerosis or syphilitic aortitis may each produce it Again, coronary thrombosis does

not cause myocardial infarction if the collateral circulation is sufficient to preserve the life of the threatened tissue. It follows that coronary thrombosis and myocardial infarction are not synonymous terms and should not be confused, the former means no more than its literal sense implies; the latter means death of a localised mass of heart muscle

Anatomy of the coronary circulation The site and extent of the infarct depend upon the vessel or vessels occluded, upon the capacity and efficiency of collateral channels, and upon the anatomy of the coronary circulation

There are two main coronary arteries, left and right. The left divides early into an anterior descending branch and into a left circumflex the large anterior descending branch runs down the interventricular groove to the apex of the heart, and nourishes the anterior part of the right ventricle, the interventricular septum, and the anterior and apical part of the left ventricle; the smaller left circumflex curls round to the back between the le[illegible]

F[illegible]

r[illegible]

branches to the region of the sinus node, to the anterior part of the right ventricle and to the posterior base of both ventricles There is a considerable degree of anastomosis between the terminal branches of these vessels, an anastomosis that increases rapidly when the blood supply to any area is threatened (Prinzmetal *et al.*, 1947) The right ventricle, supplied as it is by the two biggest coronary arteries, and offering little resistance to systolic coronary blood flow, is rarely the seat of infarction. The upper and lateral part of the left ventricle is supplied by proximal branches from both anterior descending and left circumflex vessels, and is therefore relatively safe The posterior basal region is less secure, for it is supplied only by terminal branches, some from the right coronary artery and some from the left circumflex. In having this double source of nourishment, however, it is still more fortunate than the anterior apex of the left ventricle, which is fed almost entirely by terminal rami from the anterior descending branch of the left coronary artery, although anastomotic channels can develop rapidly from the posterior descending branch of the right coronary artery The interventricular septum is supplied anteriorly by perforating branches from the anterior descending coronary artery, and posteriorly by perforating branches from the right Anastomoses are more conspicuous in the superficial layers of the myocardium than in the inner layers (Prinzmetal *et al*, 1948); they are also at a physiological disadvantage when near the endocardium because they are subjected to a higher intramyocardial pressure (Johnson *et al.*, 1939)

Site of thrombosis and infarction. Clinically, major coronary thrombosis involves the anterior descending branch of the left coronary artery in 66 to 75 per cent of cases, the right coronary artery in 25 to 40 per cent, and the left circumflex in 5 to 33 per cent (Barnes and Ball, 1932; Appelbaum and Nicolson, 1935; Munck, 1946), thrombosis of the left main trunk is

relatively rare. These figures are conservative, for careful study of the whole coronary tree by means of radio-opaque injections reveals multiple thromboses in the majority of instances

The relative incidence of the various sites of infarction harmonises with the anatomical and physiological data, and with the sites of thrombosis In a recent analysis of 160 cases, Wartman and Hellerstein (1948) found chiefly anterior infarction in 72 per cent and chiefly posterior in 28 per cent, but there were multiple infarcts in 41 per cent Half the anterior infarcts and a quarter of the posterior infarcts also involved the interventricular septum. Right ventricular infarction rarely occurs alone, but it may complicate anteroseptal infarction of the left ventricle.

Combining figures published by Appelbaum and Nicolson (1935), Nathanson (1936), Clawson (1939), and Munck (1946), it is found that coronary thrombosis occurs without cardiac infarction in 20 per cent of cases, and that cardiac infarction occurs without coronary thrombosis in 29 per cent, in the latter group atherosclerotic occlusion may be complete or incomplete

Pathology A cardiac infarct may be difficult to distinguish with the naked eye when less than twenty-four hours old: microscopically, however, acute necrosis of the muscle fibres may be recognised by their swollen appearance and by the loss of their nuclei and striations When a few days old an infarct is discoloured and may be surrounded by a red zone of hæmorrhage or congestion Microscopically the necrosed muscle is seen to be invaded by polymorphs Older infarcts are yellowish white in colour and represent scar tissue

When necrosis involves the inner layers of the myocardium, mural thrombi frequently form against the damaged endocardium; in fact they are found in 40 to 50 per cent of all cases (Hellerstein and Martin, 1947). Local pericarditis occurs over superficial necrosis and has been reported in 30 to 75 per cent of all cases (Wartman and Hellerstein, 1948, Stewart and Turner, 1938); diffuse pericarditis develops in about 10 per cent

Myocardial softening (myomalacia cordis) may result in rupture of the heart (5 to 15 per cent) or in the formation of a cardiac aneurysm (10 to 30 per cent, according to published necropsy figures and according to the definition of an aneurysm).

Symptoms. Although the onset of cardiac infarction is sudden, premonitory symptoms are common during the preceding week or so and take the form of typical or atypical angina pectoris. Then, or without warning of any kind, and usually without any obvious precipitating cause, the major attack overwhelms the patient. It may strike indiscriminately whether the subject is asleep, at rest, performing daily routine duties, or exerting himself, and is commonly signalled by pain indistinguishable in site, radiation, and quality, from angina pectoris; but instead of passing off in a few minutes, it lasts for hours. Its intensity varies from a feeling of pressure to extreme

agony, and gives no indication of the size of the infarct. There may be no other symptoms, on the other hand there may be collapse, weakness, faintness, sweating, pallor, breathlessness, and vomiting Whilst a classical attack is characterised by pain, others present with syncope, and yet others with suffocation. In the syncopal type, which represents a vaso-vagal reaction, loss of consciousness may prevent appreciation of pain, when paroxysmal cardiac dyspnœa or acute pulmonary œdema dominates the scene, the patient usually admits pain on close questioning

Physical signs. Unlike angina pectoris, myocardial infarction provides a wealth of physical signs and special findings When first seen the patient is usually grey, cold, sweating, obviously ill and in pain; he may be breathless and cyanosed, or he may be pale and collapsed—perhaps unconscious, on the other hand, he may present none of these features Within two or three days mild cases may look and feel well

The jugular venous pressure is sometimes a little raised during the first day or two, and the pulse rate accelerated, but in cases with a vaso-vagal reaction there may be bradycardia There may be orthopnœa, paroxysmal cardiac dyspnœa or frank pulmonary œdema in severe cases.

The blood pressure falls initially only in cases with a vaso-vagal reaction, and indeed may be elevated during the first twelve hours or so (Weiss, 1939), in animals it is similarly maintained for the first twenty-four hours (Gross *et al*, 1938), but it drops later, commonly reaching its lowest level on the third or fourth day, when systolic pressures of 80 to 90 mm of mercury are often found Thereafter it remains low for several days, or even for weeks, and then in all who survive, climbs slowly back towards its previous level, which it may or may not reach (fig 14 09) In 67 per cent of fatal cases Chambers (1947) observed no such recovery In hypertensive subjects this drop in pressure may not be recognised unless the original level is known

The heart sounds are often faint, particularly when the blood pressure is low, and there may be presystolic or protodiastolic gallop rhythm Transient pericardial friction is heard in about 10 per cent of cases, especially when the infarct is anterior. Disturbances of rhythm are not uncommon and include ectopic beats, paroxysmal ventricular tachycardia, auricular flutter or fibrillation, and any grade of heart block

Low-grade fever is the rule and may continue for several days, but rarely for more than a week Transient polymorphonuclear leucocytosis also occurs during the first few days The sedimentation rate begins to accelerate after a day or two, reaches maximum velocity towards the end of the first week, and then gradually returns to normal in an average period of six weeks from the [illegible]

[illegible] 'ready been described and [illegible] the surface of the infarct show a prominent or monophasic Q wave, initial elevation of the RS-T segment, and subsequent inversion of the T wave Anterior infarcts may

BEHAVIOUR OF BLOOD PRESSURE IN ACUTE CARDIAC INFARCTION

ESTIMATED MEAN BLOOD PRESSURE (DIASTOLIC B.P. + ⅓ PULSE PRESSURE)

200 180 160 140 120 100 80 60

CONTROL C.T 1 2 3 4 5 6 7 8

DAYS

Fig 14 09—Behaviour of the blood pressure in four cases of acute myocardial infarction

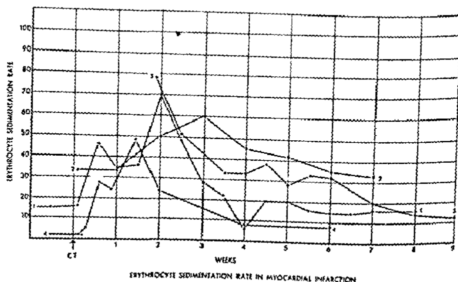


Fig 14 10—Behaviour of the sedimentation rate in four cases of acute myocardial infarction

be mapped out with precision by means of multiple unipolar chest leads, and may be chiefly anterolateral (fig 14.11) or anteroseptal (fig 14 12) The Q-T pattern is usually transmitted to lead VL and hence mainly to standard lead 1, but if the heart is electrically vertical a V5 Q-T pattern may be transmitted to lead VF, and hence to standard leads 2 and 3 The Q-T pattern of posterior infarcts is seen in œsophageal leads over the posterior surface of the left ventricle, and is transmitted to lead VF and hence to standard lead 3 (fig. 14.13a), while chest leads usually show initial depression of the RS-T segment, followed by unusually tall T waves (fig 14.13b)

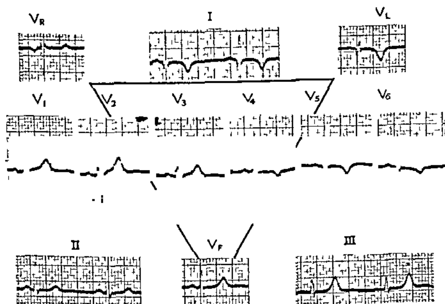


Fig 14 11—Electrocardiogram showing anterolateral cardiac infarction Maximum changes are seen in leads V5, V6, VL and standard lead I

The abnormal Q wave develops early and may persist indefinitely. Elevation of the R-T segment is usually transient, but a monophasic Q wave associated with persistent elevation of the Q-T segment is often seen with ventricular aneurysm (fig 14 14) Primary inversion of the T wave appears in a few days, reaches a maximum within two or three weeks, and then gradually reverts towards normal, but slight inversion, with Pardee coving of the RS-T segment, may persist in one or more leads (fig. 14 15).

The diagnosis of acute cardiac infarction is practically untenable if serial electrocardiograms remain normal in all the recognised leads, but an initial electrocardiogram may be normal occasionally if taken within a few hours of the onset

In differential diagnosis great stress is laid on the abnormal Q wave, for

this occurs in no other condition It must, of course, be distinguished from a normal Q wave measuring 2 or 3 mm., and a monophasic downward deflection in standard lead 3 should not be accepted as a Q wave unless Q is also prominent in standard lead 2 and in lead VF (fig. 14.16). Elevation of the RS-T segment is also seen in pericarditis (page 342), and opposite large S waves in appropriate leads in left ventricular preponderance (page 426) and left bundle branch block; but the contour of the S-T segment and the general pattern is different, as described elsewhere.

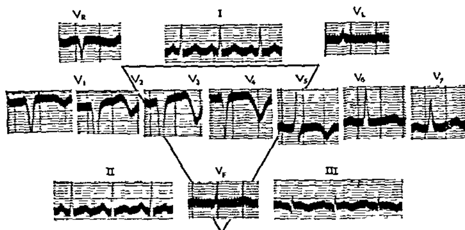


Fig 14.12—Electrocardiogram showing anteroseptal cardiac infarction. Maximum changes are seen in leads V3 and V4

Primary inversion of the T wave alone is less conclusive evidence of infarction, for it may be seen in a variety of conditions including toxic myocarditis, pericarditis, carbon monoxide poisoning, myxœdema, certain biochemical states, and following paroxysmal tachycardia. However, the depth and sharpness of the inversion usually exceed that in all other types, and its association with upward coving of the RS-T segment is practically diagnostic. Changes in serial graphs are less helpful, because nearly all the primary T wave changes mentioned above are also transient.

Bundle branch block, mostly left, occurred in 7 3 per cent of 700 cases of angina pectoris and in 8.9 per cent of 328 cases of cardiac infarction reported by Salcedo-Salgar and White (1935). Conversely they found that ischæmic heart disease accounted for approximately 50 per cent of 181 cases of intraventricular block of all types Master, Dack and Jaffe (1938) found the incidence of bundle branch block in acute coronary occlusion to be 12 per cent in 1,058 cases collected from the literature, and 15 per cent in 375 cases of their own. Intraventricular block does not necessarily imply septal infarction in these cases, and, of course, may precede the acute episode. Its importance lies in the fact that it may mask the electrocardiographic signs of cardiac infarction; for as explained on page 90 there can be no

VR I VL

V1 V2 V3 V4 V5 V6

II VF III

Fig 14 13 (a)—Electrocardiogram showing posterior cardiac infarction Characteristic changes are seen in leads VF and hence in leads 2 and 3 The ST segment is depressed in lead V4

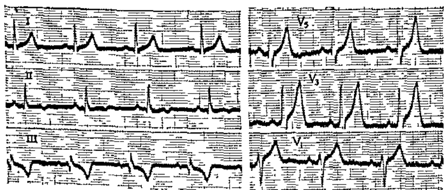
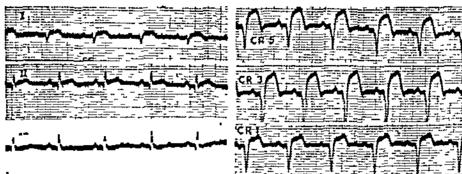
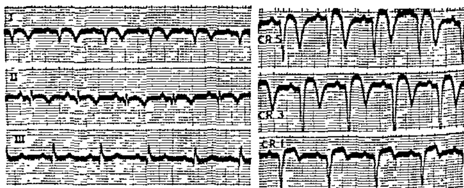


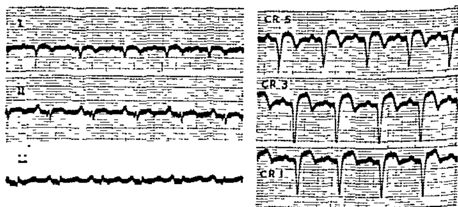
Fig 14 13 (b)—The later stage of posterior infarction showing unusually tall T waves in chest leads



(a) 29th November 1941



(b) 15th December 1941



(c) 3rd March 1942

Fig 14 14—Electrocardiogram showing widespread monophasic Q waves and persistent elevation of the ST segment associated with ventricular aneurysm.

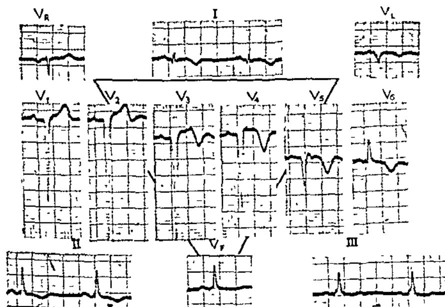


Fig. 14 15—Electrocardiogram of a case of old cardiac infarction showing persistent Q waves and Pardee coving of the ST segment in anterior left ventricular surface leads and their counterparts (leads VL and standard lead I). The infarct occurred 14 months previously

VR I VL

V1 V2 V3 V4 V5 V6

II VF III

Fig 14 16—Electrocardiogram in a case of pregnancy showing a prominent Q wave and inversion of the T wave in lead 3 due to cardiac rotation· note the absence of a pathological Q wave in lead VF and the presence of an S wave in standard lead 1

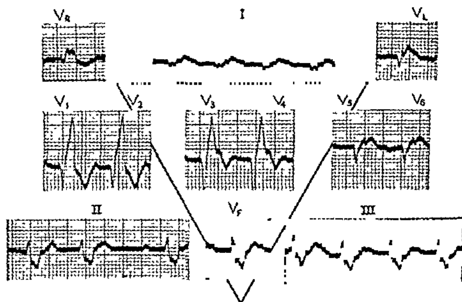


Fig. 14.17—Electrocardiogram showing typical appearances of anterior cardiac infarction in the presence of right bundle branch block.

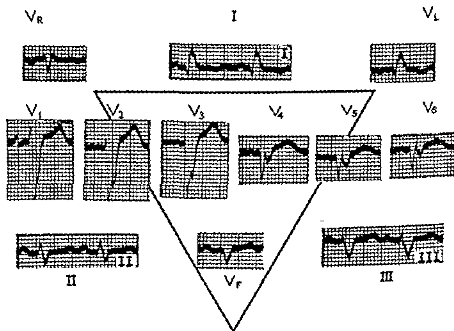


Fig. 14.18—Electrocardiogram showing typical appearances of anterior cardiac infarction in the presence of left bundle branch block

Q wave in leads facing the surface of the left ventricle in cases of left bundle branch block unless the septum is also necrosed, and the gross deformity of the R-T component may overshadow RS-T changes due to the infarct. Somerville and Wood (1949), however, found that the characteristic Q-T pattern of an infarct could be recognised in nearly all cases complicated by right bundle branch block (fig 14.17), and in about half those with left bundle branch block (fig 14.18).

Electrocardiography may be of great value in the diagnosis of myocardial infarction months or years after the event, an abnormal Q wave, local dwarfing of R, or primary inversion of the T wave in one or more left ventricular surface leads or their counterparts being particularly helpful

Radiological findings Fluoroscopy is impracticable during the acute stage of the illness, but may be useful later. An infarct on the left border of the heart near the apex may form a ledge (fig 14.19) In normal hearts pulsation is seen around the whole surface of the left ventricle, in myocardial infarction there may be local absence of pulsation, or pulsation may be locally paradoxical, a portion of the ventricle expanding while the rest contracts this area of absent or paradoxical pulsation represents the infarct, and may be seen on the left border of the heart towards the apex, or on the diaphragmatic surface of the left ventricle (with the aid of gas in the stomach), for some reason posterior basal infarcts are less easily visualised Interpretation of pulsation as seen on the fluoroscope is by no means easy, and requires considerable experience of normal variation The kymograph, a simple device for obtaining a permanent skiagraphic record of cardiac pulsation, has been used with some success as an aid in analysing the findings (fig. 14.20), the electrokymograph is even better But absence of pulsation at the apex may also be seen occasionally in hypertensive heart failure (fig. 14 21).

Ventricular aneurysm is more easily recognised, particularly when situated towards the apex or left lateral border (fig 14 22) It should not be confused with a dilated left auricle (fig 14 23) or with an intrapericardial hæmatoma (fig 14 24) Increased density and unfolding of the aorta, due to atheroma, with or without calcification, may be seen in many cases, but cannot be regarded as evidence of coronary atherosclerosis, calcified coronary arteries (Snellen and Nauta, 1937) offer more convincing proof, but even these do not necessarily signify ischæmic heart disease

Apart from the changes mentioned, the size and shape of the heart are usually normal in cases of uncomplicated cardiac infarction, enlargement is commonly due to heart failure or to coincident hypertensive heart disease.

Complications. The acute stage lasts on the average for six weeks, during the earlier part of which many complications may arise, the gravest danger being abrupt death from ventricular fibrillation (fig 14 25), about 10 per cent of all cases die in this way Other disturbances of rhythm are also relatively common and include ventricular ectopic beats, paroxysmal ven-

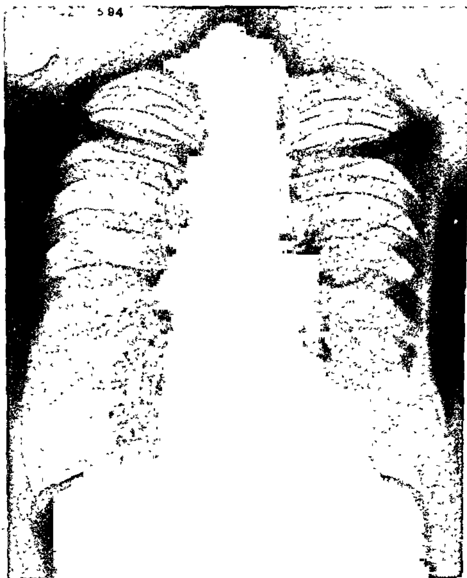


Fig 14 19—Skiagram in a case of anterior cardiac infarction showing a ledge on the left border of the heart

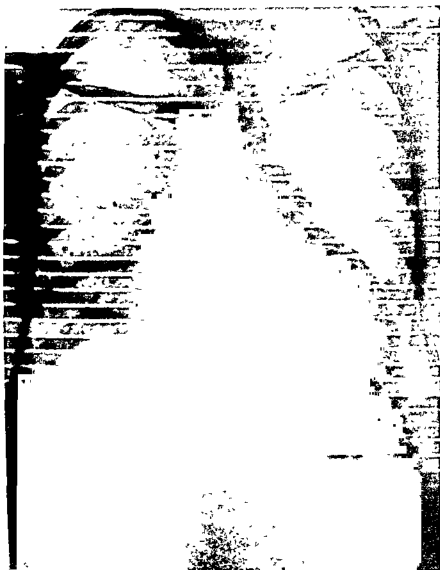


Fig 14 20—Kymogram of a case of anterior cardiac infarction showing an area of absent pulsation on the left border of the heart near the apex

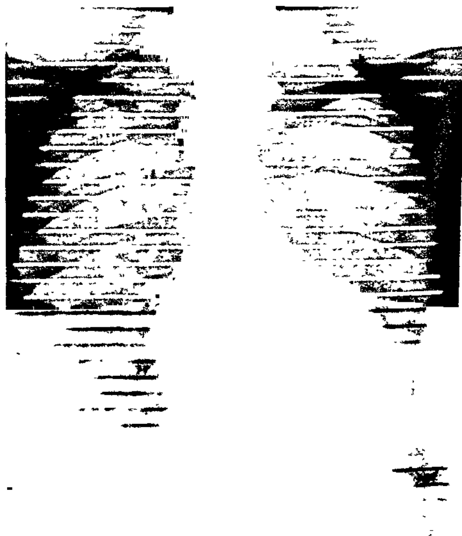


Fig 14 21—Kymogram of a case of hypertensive heart failure showing absence of pulsation at the apex

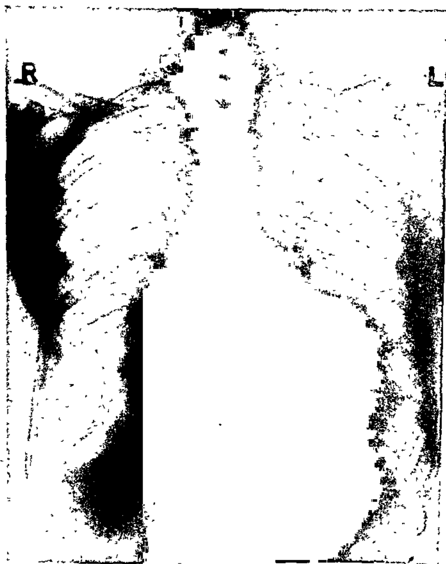


Fig 14 22—Skiagram of a case of ventricular aneurysm

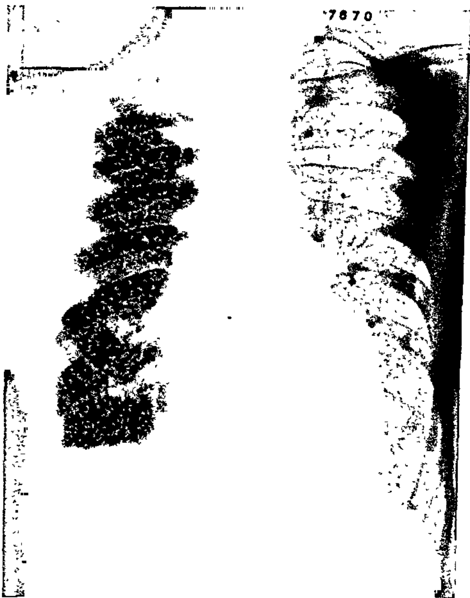


Fig 14 23—Skiagram of a case of organic mitral incompetence showing a dilated left auricle on the left border of the heart

ventricular tachycardia, paroxysmal auricular flutter and fibrillation, nodal rhythm and heart block. They should be regarded seriously because they may herald ventricular fibrillation or precipitate heart failure.

Left ventricular failure or congestive heart failure is particularly serious and is responsible for as many deaths as ventricular fibrillation; moreover, it increases the risk of phlebothrombosis and pulmonary embolism.



Fig. 14.24—Skiagram of a case of stab-wound of the heart showing a hæmatoma on its left border (successfully evacuated later)

Thrombo-embolic lesions in various situations are detected clinically in a little over 10 per cent of cases, and may be found at necropsy in about 45 per cent (Hellerstein and Martin, 1947). The dangerous period is from the fifth or sixth day to the end of the third week, when the clotting time is shortened (Ogura *et al.*, 1946). Phlebothrombosis in the legs resulting in pulmonary embolism is by far the most common, and is responsible for

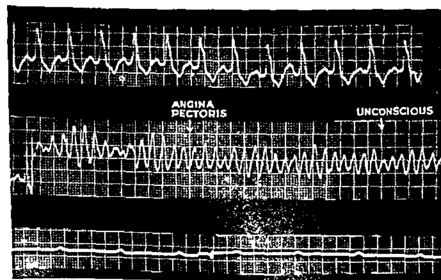


Fig. 14.25—Electrocardiagram showing the mode of death in a case of ischæmic heart disease: ventricular fibrillation developed while a routine graph was being taken

10 per cent of deaths following cardiac infarction Cerebral thrombosis or embolism is next in importance, accounting for 5 per cent of such deaths Hellerstein and Martin give the incidence of various thrombo-embolic lesions as follows:

	Per cent
Pulmonary	23 5
Renal	14.4
Splenic	8 8
Cerebral	7.7
Peripheral arteries	5.5
Mesenteric	1.9
Carotid or aortic	0.5

Although mural thrombi occur in 44 per cent of all cases, they are not responsible for more than 10 per cent of these lesions, for the latter have been found in 39 per cent of cases without mural thrombi, and the total incidence of thrombo-embolic lesions is little higher (45 per cent) Thus, massive pulmonary embolism is invariably from phlebothrombosis, never from mural thrombi, and cerebral vascular accidents are commonly the result of local thrombosis (Bean, 1938)

Cardiac rupture occurs in less than 1 per cent, or in 10 per cent of fatal cases, it is not necessarily a dramatic event, for the perforation may be small, and the signs and symptoms may be those of cardiac compression from hæmopericardium, such cases may live a week or more. Perforation of the interventricular septum is seen occasionally, and gives rise to the sudden development of a coarse systolic thrill and murmur in the third and fourth intercostal spaces towards the sternum Heart failure has ensued rapidly in most of the cases reported (e g Leonard and Daniels, 1938). Although the perforation may look small at necropsy and the track tortuous, the shunt during life may be considerable as estimated by means of cardiac catheterisation

Left ventricular aneurysm may be found at necropsy in as many as 22 per cent of fatal cases (Wartman and Hellerstein, 1948), but is less often recognised clinically In the series referred to above, 25 were anterior and 10 posterior, five of them ruptured The condition arises early and may be well developed by the time the patient is allowed up for fluoroscopy. The X-ray appearances have already been described (page 397). Clinically it is suggested by an unusual pulsation in the region of the apex beat when left ventricular enlargement is improbable on other grounds. The electrocardiogram usually shows a monophasic Q wave and conspicuous and rather persistent elevation of the Q-T segment over the aneurysm, while the main QRS deflection is often upright in lead VR (Goldberger and Schwartz, 1948) (fig 14 14) If rupture does not occur during the first few weeks the prognosis is fair.

Pericarditis may be of three kinds: (1) a transient friction rub may be heard over an anterior apical infarct, and represents local pericardia reaction; (2) there may be widespread pericarditis with friction heard at all areas or at a distance from the lesion, which may complicate either anterior or posterior infarcts; (3) there may be hæmopericardium resulting from ventricular perforation. *Local pericarditis does not alter the electrocardiographic* pattern of infarction; but widespread pericarditis may do so, and hæmopericardium invariably does (fig. 14.26). Pericardial friction of one kind or another is heard in about 10 per cent of cases

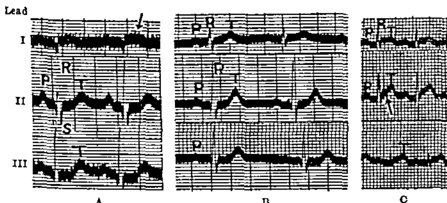


Fig 14 26—*Cardiac infarction complicated by perforation and hæmopericardium*
A Original anterior cardiac infarction
B After recovery
C After perforation of infarct (hæmopericardium)

After-effects. The subsequent course is determined by the effect of the occlusion on the total coronary circulation Angina pectoris may develop, or if it was present before it may be worse, on the other hand, if previous pain was due to local ischæmia at the site of the recent infarct, angina may improve or temporarily disappear Congestive failure may also develop later, and may cause the disappearance of angina. Later cardiac rupture is rare, and usually denotes fresh coronary occlusion, even when the perforation is through the old infarct. Less than 10 per cent of ruptured hearts are due to an old ventricular aneurysm (Munck, 1946)

Differential diagnosis In the differential diagnosis of myocardial infarction, many conditions must be borne in mind, the most confusing are massive pulmonary embolism, acute pericarditis, dissecting aneurysm of the aorta, diaphragmatic hernia, œsophageal or gastric dysfunction, and acute pancreatitis, but diaphragmatic pleurisy, especially when bilateral, disease of the gall-bladder, perforated duodenal ulcer, epidemic myalgia, and pain referred from the spine may give rise to difficulty. In pulmonary embolism the most important clue is early engorgement of the cervical

veins and immediate hypotension, whilst rhythm changes are very rare; otherwise, both symptoms and signs may be indistinguishable from those of coronary thrombosis, and even limb-lead electrocardiograms may resemble those of posterior cardiac infarction Fortunately, however, chest-lead graphs are diagnostic (page 450). Acute pericarditis may simulate cardiac infarction closely, but may be distinguished by the electrocardiogram (page 342). Dissecting aneurysm is characterised by radiation of pain to the back and downwards, by hypertension, by the absence of electrocardiographic change, by the development of aortic incompetence, and perhaps by signs of involvement of carotid, subclavian, renal or femoral arteries (page 523) Diaphragmatic hernia should be considered when there are no changes in temperature, white count, E S R, and electrocardiogram, and may be diagnosed by means of a barium meal with the patient in the head-down position. Œsophageal or gastric pain may be felt in the centre of the chest and may resemble the pain of cardiac infarction, but physical examination is entirely negative, the electrocardiogram remains normal, and the subsequent course is benign Acute pancreatitis may be recognised by the urinary diastase test

Treatment Patients should be confined to bed at once and should remain there for three to six weeks, or longer, according to the severity of the illness and to the behaviour of the sedimentation rate and electrocardiogram If the blood pressure is low and the patient faint or dizzy, he may have to lie flat, otherwise, and particularly if there is any sign of failure, he should be propped up against a back-rest in order to reduce the work of the heart (page 158).

Semi-starvation for the first few days followed by an 800-calorie diet during the dangerous period practically halves the mortality rate (Master *et al*, 1936) Fruit drinks and soft, stewed or fresh fruit with sugar is all that should be allowed for the first forty-eight hours The quality of the later light diet matters less than its bulk and calorific value, but should contain little sodium if there is any evidence of failure.

The most beneficial drug in the acute phase is morphine, which should be given in adequate doses and as often as required to relieve pain and distress, and to induce rest and sleep Excellent results are obtained when pain is severe by giving it intravenously in a dose not exceeding ¼ of a grain (15 mg) dissolved in at least 2 ml of sterile water or saline, and at a slow rate, three minutes being taken over the injection

Quinidine, 3 to 5 grains (0 25 G.) t.d.s, may be given in the hope of preventing ventricular fibrillation and other changes of rhythm Results are difficult to assess, but on the whole seem to be encouraging; certainly, quinidine prevents ventricular fibrillation in dogs (Wegria and Nickerson, 1943), and the doses recommended are without danger.

Heparin and dicoumarol (page 454) have been used widely in recent years to prevent extension of coronary thrombosis and thrombosis elsewhere. The frequency of pulmonary embolism and of cerebral thrombosis

has already been noted; the former was directly responsible for 6 5 per cent of deaths in a series of 200 fatal cases reported by Eppinger and Kennedy (1938), was present in 24.5 per cent of the total, and in 32 7 per cent of those with congestive failure. These are average figures and provide good grounds for anticoagulant therapy. The results of a preliminary analysis of 800 cases so treated (collected by a special committee of the American Heart Association) have been given by Vander Veer, Marshall and Kuo (1948) as follows:

	Controls per cent	*Cases treated with anticoagulants per cent*
Death rate	23	13
Thrombo-embolism . .	19	9

The coronary vasodilators, with the possible exception of aminophylline, do not relieve the pain of cardiac infarction, and do not influence its course; aminophylline, 0 2 G. t d s. or four-hourly, may perhaps improve the collateral circulation and may help to prevent cardiac asthma.

The only other drugs used at all frequently are bromide and phenobarbitone to allay anxiety in apprehensive patients.

Adrenaline should be avoided, no matter how low the blood pressure, for the gravest danger is ventricular fibrillation, and the drug most likely to produce it, adrenaline. Digitalis and strophanthin are rarely indicated and are dangerous for the same reason (Travell, Gold and Modell, 1938) They may be considered, however, when congestive heart failure is becoming serious or when auricular fibrillation or flutter with rapid ventricular rate persist for more than twenty-four hours, but especial care must be taken to avoid an overdose Coramine, strychnine, cardiazol, and other similar remedies of the stimulant class are not advised

Other measures may be necessary when there are complications mercurial diuretics and a low sodium diet are useful in the event of failure; ephedrine, ½ gr (32 mg) t.d s, should not be withheld if Stokes-Adams attacks complicate heart block; and bolder doses of quinidine may be needed to combat paroxysmal ventricular tachycardia

If the course is benign and the patient looks and feels well, he may be allowed up after three weeks, provided the sedimentation rate has returned to normal and the electrocardiogram does not show a large infarct. Most cases require a month in bed and a further fortnight resting at home on a couch, but those with complications should remain in bed for six weeks or longer.

Six weeks' to three months' convalescence is usually needed, while the patient regains his confidence and gradually resumes his ordinary activities Radical change of employment is rarely practicable in this age-group, but lighter work and less responsibility may have to be advised Relatively good

recovery from the first attack is the rule; but severe angina or recurrent congestive failure may cause total incapacity after subsequent attacks.

Prognosis. The mortality rate in acute cardiac infarction has been about 25 per cent for all attacks not specially treated; with prompt nursing attention, initial semi-starvation, and no interference it is said to be 16 5 per cent (Master *et al.*, 1936), and with anticoagulant therapy 13 per cent (Vander Veer *et al.*, 1948) With the added help of a low sodium diet and quinidine, the mortality rate for all attacks should not exceed 10 per cent Such figures exclude cases of sudden death due to coronary thrombosis; they refer only to those which survive long enough to receive medical attention. The mortality rate in first attacks has been about two-thirds that in all attacks

Preceding angina pectoris or hypertension has no influence on the prognosis, but diabetes mellitus is adverse. Whether the infarct is anterior or posterior matters little, but involvement of the septum, multiple lesions, and extensive necrosis, as judged by the electrocardiogram, are bad omens. Initial shock, prolonged hypotension, a small pulse pressure, arrythmias, cardiac enlargement, congestive heart failure, and thrombo-embolism are naturally serious (Katz and Mintz, 1947). Both in hypertensive and normotensive subjects, the greater the fall in blood pressure the worse the outlook, again, those whose blood pressure fails to climb back towards their previous levels fare badly (Chambers, 1947)

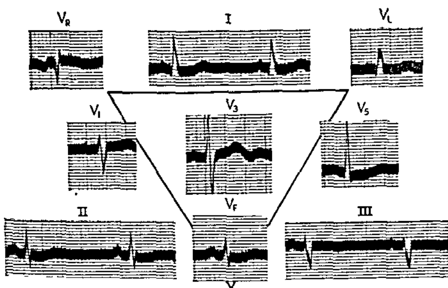
The further outlook in those who make a satisfactory recovery from their first attack of cardiac infarction does not differ radically from that in angina pectoris as a whole, reliable figures are not available, but the average life expectancy may be estimated at about seven to eight years.

The factors which influence the ultimate prognosis are also the same as those in angina (page 380)

ACUTE CORONARY INSUFFICIENCY

The term acute coronary insufficiency has been proposed by Master and his colleagues (1947) to describe those cases of ischæmic heart disease that cannot properly be called angina pectoris or cardiac infarction, but that appear to be something between the two

The physiological basis for the condition is similar to that for angina pectoris, but the responsible precipitating factors are prolonged. For example, prolonged increase of cardiac work may be due to paroxysmal tachycardia, auricular flutter, hypertensive crises, thyrotoxic crises, and to an overdose of certain drugs such as adrenaline, prolonged diminution of the coronary blood flow may be due to anything that seriously lowers the cardiac output and blood pressure, e g. hæmorrhage, shock, massive pulmonary embolism, and vaso-vagal syncope; prolonged reduction of the oxygen content of the arterial blood results from asphyxia, carbon monoxide poisoning, and acute anæmia. In all these conditions the nutritional de-



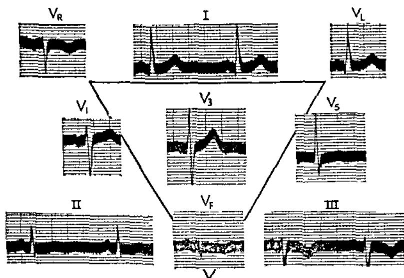


Fig 14 27—Electrocardiogram showing persistent depression of the ST segment in a case of acute coronary insufficiency Recovery followed six weeks' rest and dicoumarol

mands of the myocardium may be inadequately met, especially if occlusive coronary atherosclerosis is also present, and subendocardial necrosis of any part of the left ventricle may occur. The inner third of the muscle suffers most, as in angina pectoris, owing to the intramyocardial pressure gradient.

The clinical features may resemble a prolonged attack of angina or atypical cardiac infarction, on the other hand, the condition may be clinically silent The electrocardiogram shows depression of the RS-T segment in left ventricular surface leads and their counterparts, similar to that seen during an attack of angina pectoris or during artificial hypoxia (fig. 14.27).

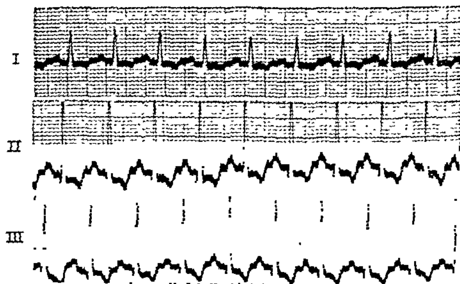
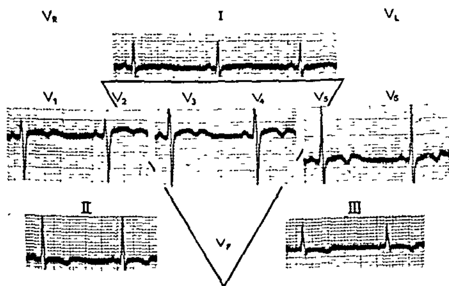


Fig 14 28—Electrocardiogram showing transient inversion of the T waves following prolonged circulatory collapse with extreme tachycardia, without evidence of structural disease of the heart

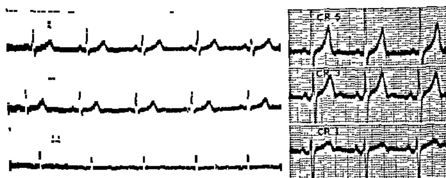
Transient inversion of the T wave in the same leads may develop later in the attack and may last for several days after the circulation has returned to normal (fig. 14.28). True inversion of the T waves is well seen in carbon monoxide poisoning (fig 14 29)

Acute coronary insufficiency as so defined may explain the occurrence of true heart failure in the later stages of shock (Wiggers, 1947), and the readiness with which heart failure develops during infusions in the hyperkinetic stage of severe hæmorrhage or acute anæmia (Sharpey-Schafer, 1944). It may also explain the poor functional state of the heart too long subjected to tamponade, and the development of true heart failure in occasional cases of constrictive pericarditis

A special type of acute coronary insufficiency occurs after coronary thrombosis without cardiac infarction. This is described on page 384



(a) Third day.



(b) Twelve days later

Fig 14 29—Transient inversion of the T waves due to carbon monoxide poisoning

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CHAPTER XV

HYPERTENSIVE HEART DISEASE

HYPERTENSIVE heart disease is but one facet of the whole problem of systemic hypertension It is necessary to consider this problem first

DEFINITION

Hypertension implies elevation of the basal blood pressure above the normal limits of 145/90 mm Hg Physiological vasoconstriction due to emotion, to cold, or to other trivial cause, is common, and modifies the significance of casual high readings of the order of 160/90 mm. Hg. The basal pressure is that obtained when the subject is lying down, and when successive readings at five-minute intervals have dropped to a steady level. Strictly speaking, the subject should have had nothing to eat or drink for twelve hours, and the room temperature should be about 70°F.; but these points are impracticable

When elevation of the blood pressure shows disproportion between systolic and diastolic levels, systolic bias favours rigidity of the aorta and large vessels as in atherosclerosis, or increased force of cardiac contraction as in thyrotoxicosis, whereas diastolic bias favours vasoconstriction, as in true hypertension It is therefore permissible to speak of systolic or diastolic hypertension

VARIETIES OF HYPERTENSION

Hypertension may be paroxysmal, as in phæochromocytoma of the adrenal medulla, transient, as in acute nephritis and toxæmia of pregnancy; or persistent, as in chronic nephritis, chronic pyelonephritis, surgical kidney, coarctation of the aorta, and essential and malignant hypertension. High blood pressure accompanying thyrotoxicosis and the climacteric is coincidental. statistical analysis shows no significant correlation, and the pressure does not fall when these disorders are corrected (Bechgaard, 1946) The blood pressure in obese subjects may appear to be higher than it really is, owing to the unreliability of the cuff method of measurement when applied to a fat limb, lower pressures may be recorded by direct arterial puncture. Under certain conditions, e.g. during a rigor when there is intense vasoconstriction, or when the main artery to the limb is partly occluded, the blood pressure reading may be much lower when measured by the cuff method than when measured by direct arterial puncture, indeed it may be immeasurable by ordinary means when direct puncture proves it to be in the region of 100 mm. Hg. Such fallacies must be constantly

borne in mind. Hypertension associated with mitral stenosis is almost certainly a matter of chance, apart from the transient rise of pressure which may result from heart failure.

INCIDENCE

In 1928 hypertension accounted for 14.8 per cent (Bell and Clawson) to 20 per cent (Fahr) of all deaths in the U S A. in people over 50 years of age; British estimates are similar. About 5 per cent of young adults, 30 to 40 per cent of subjects over 40, and 65 to 75 per cent of those over 70 have some degree of hypertension (Master *et al.*, 1943); the lower figures apply to [illegible] ar [illegible] 19[illegible] tension in persons under 40 years of age is commonly renal less than a third of his series were essential, and he encountered no primary malignant cases under the age of 34

The sex incidence is about equal, men being rather more frequently affected in the upper classes (Janeway, 1913; Ehrstrom, 1918), women in the lower (Blackford *et al.*, 1930; Bechgaard, 1946) Malignant hypertension, however, effects three men to one woman

About 80 to 85 per cent of cases of persistent hypertension are essential, about 2 per cent are primary malignant, and most of the remainder are renal.

High blood pressure appears to be linked with civilisation· it is said to be rare or uncommon in China, amongst orientals generally (Harris, 1927), and in negroes (Donnison, 1929), but it is as common or more common in civilised negroes in the U S A. as in the white population (Fishberg, 1939).

PATHOGENESIS

Paroxysmal hypertension is due to an excess of circulating adrenaline released by a phæochromocytoma of the adrenal medulla (Beer, King and Prinzmetal, 1937).

Transient hypertension in acute nephritis appears to depend upon a nervous rather than a humoral agent (Pickering, 1943), and may be due to extra-renal factors (Kylin, 1926) There is reason to believe that acute nephritis is an allergic vascular reaction to the products of remote bacterial infection (Cavelti and Cavelti, 1945) usually but not exclusively streptococcal, the brunt of the attack falling on the glomerular tufts, but the capillaries elsewhere not escaping entirely. General vasospasm may cause the hypertension

Hypertension in *toxæmia of pregnancy* may be transient and behave like that in acute nephritis or it may be persistent and resemble essential or malignant hypertension (Golden, Dexter and Weiss, 1943)

High blood pressure in *coarctation of the aorta* (page 208) probably results from diminution of the renal blood flow. It does not occur experimentally if the aorta is constricted below the origin of the renal arteries (Rytand, 1938).

Hypertension resulting from *chronic nephritis*, *chronic pyelonephritis* (Schoen, 1930, Longcope and Winkenwerder, 1933), and certain *surgical kidneys* (Braasch, Walters, and Hammer, 1940) is almost certainly attributable to a humoral agent liberated by the diseased kidney (Pickering, 1943)

ETIOLOGY OF ESSENTIAL HYPERTENSION

Certain predisposing factors must be considered first.

Heredity According to Platt (1947), essential hypertension could be a hereditary disease conveyed as a Mendelian dominant with a rate of expression of more than 90 per cent. This may be an extreme view, but the importance of the hereditary factor cannot be denied Thus Ayman (1934), studying 277 families, found hypertension in the children in 3.1 per cent of the families when both parents were normal, in 28.3 per cent when one parent was hypertensive, and in 45.5 per cent when both parents were hypertensive. Again, in an investigation based upon 256 members of 30 families, Hines (1940) found that the children were hyper-reactors to the cold pressor test in 43 4 per cent when one parent was either hypertensive or a hyper-reactor, and in 95 per cent when both parents were effected In Bechgaard's series of over 1,000 cases of persistent hypertension, which included 20 7 per cent possible renal cases (in which there is no hereditary factor), one or both parents were seriously hypertensive in 75 per cent

Hyper-reaction to pressor agents The excessive reaction of hypertensives to the cold pressor test of Hines (1940) is the best example The test is carried out as follows the basal blood pressure is first recorded in the usual way, the subject's free hand is then plunged into ice-cold water (3° to 5°C) to just above the level of the wrist, and immersed for one minute, while the blood pressure is recorded at half-minute intervals. In 8.5 per cent of normal persons the blood pressure rises an average of 12.4/10.1 mm Hg, and returns to its previous level within two minutes. A rise of more than 20/15 mm. Hg is regarded as a hyper-reaction Patients with established essential hypertension show an average rise of 46 6/30 9 mm Hg, 95 per cent being hyper-reactors Follow-up studies indicate that apparently normal individuals who are hyper-sensitive to the cold pressor test are likely to develop persistent hypertension. Hines also claims that high casual readings due to emotion have the same significance; but this is not substantiated by the subsequent histories of patients with Da Costa's syndrome (Grant, 1925; Wood, 1941).

Holding the breath for 20 seconds may also be used as a pressor agent

in much the same way, and compares favourably with the cold pressor test (Ayman and Goldshine, 1939).

Other factors. The influence of civilisation, and of sex in malignant hypertension, has already been mentioned

Structural changes in the vessels Certain structural vascular changes often found associated with hypertension have been proved to play no part in its production. Atherosclerosis is innocent in this respect unless a plaque constricts the renal artery; increased rigidity of the aorta and great vessels may raise the systolic pressure, increase the pulse volume, and accelerate the speed of the pulse wave, but it has little influence upon the mean blood pressure. Calcification of the media of medium-sized arteries has a similar effect. The characteristic vascular lesion which is the signature of malignant hypertension, necrosing afferent glomerular arteriolitis, is a result, not a cause, of extreme hypertension Multiplication of the internal elastic lamina, and hypertrophy of the media of small arteries and arterioles, are also effects, not a cause, of sustained hypertension Hyaline thickening of the intima, especially of the afferent glomerular arterioles, found in 98 per cent of cases of essential hypertension, is the only vascular lesion possibly to blame which has not yet been proved to be a result of high blood pressure (Pickering, 1943).

Experimental studies. The classical experiments of Goldblatt (1934 *et seq.*) proved that persistent hypertension could be induced in dogs by constricting both renal arteries; unilateral constriction failed unless the other kidney was removed. Hypertensive retinopathy and widespread arteriolar necrosis similar to malignant hypertension in man were reproduced by more severe constriction, but the renal vessels distal to the clamp were spared Similar results were obtained in rabbits by Wilson and Pickering (1937) In 1939, Wilson and Byrom succeeded in causing persistent hypertension, benign or malignant, in rats by constricting only one renal artery The vessels in the other kidney then showed changes comparable in all respects to those seen in benign or malignant hypertension in man

The conclusion that the difference between essential and malignant hypertension is merely one of degree is supported by the occasional development of malignant changes in practically all varieties of hypertension, includ[illegible] the early [illegible] necros[illegible] merely a late consequence (Castleman and Smithwick, 1943)

Biochemical hypothesis concerning the cause of hypertension Experimental hypertension of the kind just described is believed to depend upon the liberation of an excess of renin by the ischæmic kidney Renin combines with an enzyme, hypertensinogen, which is a normal constituent of the [illegible] or angio-tonin [illegible] e destroyed by

There is, as yet, no direct proof that essential hypertension in man is caused by this mechanism, although it seems to explain renal hypertension. It may also explain rare cases of hypertension associated with atherosclerotic obstruction of one or both renal arteries (Yuile, 1944) It should be noted that unilateral renal disease is capable of causing hypertension in man; in other words, man behaves like the rat in this respect, not like the dog or rabbit.

Physiology of the circulation in essential hypertension. In essential hypertension vasoconstriction affects chiefly the efferent glomerular arterioles of the kidney, the intraglomerular pressure being raised and the cortical blood flow diminished, obviously, if the latter were due to vasoconstriction proximal to the glomeruli, the intraglomerular pressure would be lowered. Blood appears to be diverted from the renal cortex into other channels. The classical studies of Trueta and his colleagues (1947) make it highly probable that the juxta-medullary by-pass provides the principal diversion. The vessels of the skin and brain are constricted more or less sufficiently to prevent an increased blood flow through these territories; on the other hand, the arterioles in skeletal muscle, and probably in the heart, are little if at all constricted, so that they may passively yield to the raised pressure, and take some of the shunt The behaviour of the splanchnic vessels remains to be investigated The cardiac output, blood volume, and blood viscosity are normal Vasoconstriction appears to be humoral rather than nervous in mechanism (Pickering, 1943). Hypertensin causes a similar type of vasoconstriction the chief effect is on the efferent glomerular arterioles; the skin is involved only to the extent of preventing secondary increase of blood flow; the skeletal muscles take some of the shunt. That hypertensin is the humoral cause of essential hypertension is therefore an attractive hypothesis Pickering remarks that the brain and heart, being two of the most important organs in the body, are provided with special pressor mechanisms, the carotid sinus and aortic arch, which respond to falling intravascular pressure by causing vasoconstriction, as the nature of these organs demands that appropriate adjustments are immediately executed, it is natural that the mechanism of this vasoconstriction is nervous. But the kidneys are just as vital, and it would therefore harmonise with general principles if they too were provided with a pressor mechanism to insure adequate intraglomerular pressure without which filtration would cease; but there is no necessity for *sudden* adjustments, but rather for prolonged ones. A humoral mechanism would meet the requirements nicely.

Nevertheless, as previously stated, proof that essential hypertension in man is due to excessive liberation of renin is lacking. Transfusion experiments have failed to demonstrate a pressor agent in the venous blood of hypertensive subjects; and Light and I (1939) failed to demonstrate a pressor agent in a pint of blood taken from the renal vein of a patient with malignant hypertension, and transfused into a boy of nine. Even if the humoral mechanism were proved to be the renin-hypertensin system,

we should still be ignorant of the cause of its hyperactivity

The most promising line of investigation seems to be that recently opened up by Trueta and his colleagues at Oxford. They have shown that blood reaching the kidney has two alternative routes: (1) through the glomeruli of the cortex, (2) through a juxta-medullary by-pass Blood may be diverted from the cortex in varying degree as a result of emotion, shock, crushing injuries, hæmorrhages, certain drugs, certain bacterial toxins, and probably by innumerable other agents. In cases of Bright's disease they have noticed degenerative changes in the juxta-medullary glomeruli consistent with constant operation of the shunt. The significance of these findings will not be overlooked, particularly their suggestion that the juxta-medullary by-pass may act as a functional Goldblatt clamp.

CLINICAL FEATURES

PAROXYSMAL HYPERTENSION

Paroxysmal hypertension, first described by Frankel (1886), is rare, usually occurs in youthful or early middle-aged subjects of either sex, and is characterised by recurrent attacks of palpitation, headache, and vomiting; angina pectoris or even acute pulmonary œdema (Howard and Barker, 1937) may be associated Abdominal compression, as occurs on stooping, may provoke an attack; but usually there is no obvious precipitating cause During the crisis, which may last for minutes or hours, the blood pressure (systolic and diastolic) is extremely high; most of the skin is cold, pale and mottled, but the forehead, face and neck may be flushed Sweating and trembling may follow. Between attacks the patient is usually well, but persistent hypertension, occasionally malignant, develops sooner or later in the majority (Green, 1946)

A mass about the size of an orange may be felt in the abdomen in one-third of the cases, or may be demonstrated by simple skiagrams, pyelograms, or other radiological methods The adrenal medullary tumour is commonly unilateral and benign There is usually a considerable excess of circulating adrenaline or nor-adrenaline all the time, and in attacks there may be a thousand times the normal quantity (Mackeith, 1944) The electrocardiogram may show the usual pattern associated with persistent hypertension, or it may show evidence of acute left ventricular stress during attacks—inversion of the T wave in leads facing the surface of the left ventricle

Death may result from cerebral hæmorrhage, acute pulmonary œdema, or ventricular fibrillation.

Following the demonstration by Clerc and Sterne (1937) that a synthetic benzodioxan (diethyl-aminoethyl-benzodioxan) in oral doses of 0 05 G., six-hourly, relieved all symptoms immediately and prevented further attacks, the administration of this substance has been used as a diagnostic test for the condition (Cahill, 1948)

The intravenous injection of 0·025 mg. of histamine or of 300 mg. of tetraethylammonium bromide is also helpful in diagnosis, for in cases of phæochromocytoma both *raise* the blood pressure (La Due *et al*, 1948)

Treatment is surgical and may be entirely successful; but the operative mortality is about 30 per cent (Mackeith, 1944). The chief dangers are extreme hyper-adrenalism during manipulation of the tumour, and a profound drop in blood pressure following its removal.

TRANSIENT HYPERTENSION

The clinical features of acute nephritis and toxæmia of pregnancy are beyond the scope of this work, and their effect upon the heart is discussed elsewhere (page 327).

PERSISTENT HYPERTENSION

It is doubtful whether any symptoms can be ascribed to high blood pressure itself Certainly the majority of cases are discovered accidentally, or by reason of complications Headaches, fatigue, dizziness, difficulty in concentration, and palpitations, are commonly due to anxiety, whether the blood pressure is raised or not Redistribution of blood due to selective vasoconstriction may, however, determine the behaviour of two variables It was stated previously that vasoconstriction in skin and brain was more or less sufficient to prevent an increase of blood flow through these territories as a result of raised pressure the words "more or less" may now be amplified Thus more cutaneous vasoconstriction may be responsible for the pale hypertensive, less for the red, more cerebral vasoconstriction may be responsible for dizziness, failing memory, and for general mental deterioration, less for headache The more important symptoms associated with hypertension are due to cardiac, renal or cerebral complications, and will be discussed later.

The blood pressure is necessarily raised; a diagnosis of previous persistent hypertension, when the blood pressure is found to be normal, is nearly always wrong, unless there is severe hæmorrhage, shock, massive pulmonary embolism, or myocardial infarction It is customary to recognise four grades of hypertension according to the level of the diastolic pressure: between 90 and 110 mm. Hg is considered mild, 110 to 130 moderate; 130 to 150 severe; above 150 gross The systolic pressure may be at any level between 150 and 300 mm Hg, and may modify the grade accordingly. With mild hypertension it is usually between 150 and 200, with moderate hypertension between 180 and 230, with severe, between 210 and 260, with gross, between 240 and 300 Essential and nephritic hypertension may be of any grade; malignant hypertension is always severe or gross.

The pulse is firm and varies considerably in amplitude from case to case. In the more severe grades it is apt to be small; in those with marked atherosclerosis, large. Hard, tortuous or calcified peripheral arteries indicate atherosclerosis or Monckeberg's sclerosis, not hypertension—although they

may be associated. In the latter event, one or other carotid, usually the right, may be kinked, and then mistaken for an aneurysm; or carotid pulsation may be so increased in amplitude as to suggest aortic incompetence. A diminished and delayed femoral pulse associated with absent dorsalis pedis and posterior tibial pulses indicates coarctation of the aorta. Pulsus alternans (page 166) may occur in severe cases, and is usually associated with heart failure.

Retinoscopy may reveal arterial thickening, hæmorrhages, exudates or papillœdema, and should never be omitted There are five signs of arterial thickening: (1) increased tortuosity; (2) notching, pinching, or S-shaped bending of veins at arterio-venous crossings, (3) uniform or irregular narrowing of the arterial blood streams, owing to reduction in the diameter of the vascular lumina, (4) white arterial fringes or thin white lines bordering the red arterial streams, representing the thickened white walls of the arteries themselves—they are rarely seen in more than one or two places and then only for a short distance, usually on a bend, (5) the "silver wire" artery, in which a single white streak, representing a grossly thickened artery with an obliterated lumen, replaces the red column of blood. This is rare and usually signifies thrombosis Occasionally, the distal part of such an artery may be patent, due to the development of a collateral circulation

By far the most important of these signs is narrowing of the arterial lumen Normally, the apparent width of a retinal artery compared with its accompanying vein is as 5 : 5 or 4 : 5. When the artery is thickened this ratio is decreased, and may be about 3 : 5 or less. There is no better way of expressing the average calibre of the retinal arteries than by giving the approximate arterio-venous ratio

In benign hypertension it is rare to find more than notching of veins and narrowing of the arterial lumina; white arterial fringes and obliteration of the lumen usually mean nephritic or malignant hypertension

It should perhaps be added that the appearance of the fundal vessels gives little indication of the state of the cerebral vessels, the risk of stroke cannot be assessed from retinoscopy

Retinal hæmorrhage may be superficial, when it is linear or fan-shaped in appearance, or deep, when it resembles a rounded smudge Both kinds may be seen in hypertensive retinopathy, but the former is more common. Hæmorrhages are rare in essential hypertension, and when present are usually minute. They are not uncommon in nephritic hypertension, and almost invariable, sooner or later, in the malignant type

Retinal exudates are of four distinct types. (1) large hæmorrhages sometimes reveal eccentric soft white cores which may persist after absorption of the blood, (2) soft fleecy patches scattered indiscriminately over the retina are characteristic of malignant hypertension, (3) complete or incomplete star patterns, composed of hard whitish particles or dots, radiating from the macula, may be seen in chronic nephritic or in malignant hyper-

tension; (4) in diabetes mellitus, the exudate is waxy, sharply cut, and scattered, resembling pale yellow confetti. Small areas of retinal degeneration in old people should not be confused with exudates.

When papillœdema is added to the signs of hypertensive retinopathy already described, malignant hypertension should be diagnosed Conversely, malignant hypertension should rarely be considered in the absence of papillœdema.

Although chronic nephritis may be responsible, little is lost by making the other diagnosis, for if there is papillœdema the course of the disease will certainly be malignant, if acute nephritis and toxæmia of pregnancy can be excluded. The appearances may be distinguished from those of cerebral tumour by the arterial changes, by a macular star figure, or by exudates independant of hæmorrhages.

The mechanism of hypertensive retinopathy is obscure. Hæmorrhages can hardly be due to rupture of minute vessels subjected to high pressure for the capillary pressure is normal in hypertension (Ellis and Weiss, 1929-30), and in any case healthy capillaries can withstand astonishingly high pressures Papillœdema is usually associated with a high cerebro-spinal fluid pressure, but not invariably; moreover, higher C S F. pressures are found without papillœdema in cases of superior vena cava obstruction Occasionally, progressive blindness occurs

Examination of the heart usually reveals some degree of left ventricular hypertrophy. The apex beat becomes displaced to the left and downwards; the cardiac impulse becomes heaving in quality, and unusually easy to feel It is quite different from the short sharp thrust of the over-acting heart, for it is a quiet unhurried action, giving the impression of great strength The dynamic quality of the former may be compared with the first few strokes of a racing crew, galvanised into urgent action by the sound of the starting signal; the heaving impulse of left ventricular hypertrophy to the powerful steady drive maintained by the crew when it has settled down to a long hard struggle. If, with due care, the apex beat cannot be located, left ventricular hypertrophy is unlikely, even in obese subjects, unless masked by emphysema.

Presystolic gallop rhythm is common with severe hypertension, especially but not necessarily when complicated by left ventricular failure. The second sound at the base is accentuated and high pitched. Functional aortic incompetence is not uncommon and may be associated with diastolic pressures of 130 to 170 mm Hg; in other words, it may not affect the circulatory dynamics. It is due to dilatation of the aortic ring and may be compared with functional pulmonary incompetence in mitral stenosis and atrial septal defect. Pulsus alternans may sometimes be heard, especially if there is a mitral systolic murmur (Levine, 1948).

Auricular fibrillation is found in about 7.5 per cent of unselected hypertensive patients (Rothstadt, 1938), and may precipitate congestive heart failure. At first, and particularly if untreated, it may be paroxysmal; but as

a rule it soon becomes persistent, especially under the influence of digitalis and in elderly subjects. Permanent auricular fibrillation is less troublesome than paroxysmal, and tends to protect the individual from paroxysmal cardiac dyspnœa and acute pulmonary œdema Other rhythm changes are relatively rare, but include auricular flutter, paroxysmal tachycardia and all degrees of heart block.

Limitation of cardiac reserve is indicated by undue breathlessness on exertion and by poor responses to effort tolerance tests Left ventricular failure develops sooner or later in the majority of those who survive the other hazards of hypertension, and may be recognised by a history of orthopnœa, paroxysmal cardiac dyspnœa or pulmonary œdema, and by finding persistent râles at the lung bases, a diminished vital capacity and lung volume, prolongation of the crude pulmonary circulation time, and exaggeration of the pulmonary vascular shadows, as described on pages 158 to 163.

Congestive heart failure with elevation of the venous pressure, hepatic distension, and dependent œdema, follows left ventricular failure in practically all cases that survive other risks. Not infrequently, patients with hypertensive heart disease develop congestive heart failure without previous orthopnœa and paroxysmal cardiac dyspnœa No satisfactory explanation for the behaviour of these cases has yet been offered Catheter studies have proved that the right ventricular pressure is commonly normal in hypertension, and that, although it rises in left ventricular failure, the levels reached do not seem high enough to be responsible for right ventricular failure, as much higher pressures may be found in pulmonary stenosis and patent ductus without embarrassment The suggestion that the right ventricle is partly obstructed by displacement of the interventricular septum (Bernheim's Syndrome) lacks proof, but necropsy evidence is suggestive (East and Bain, 1949). "Functional pulmonary stenosis" was disproved in one case of the author's by means of cardiac catheterisation

The cardiac output is low in hypertensive congestive heart failure, but may be near normal at rest in left ventricular failure, moreover, paroxysmal cardiac dyspnœa may occur as the output rises (page 159)

The size of the heart in hypertension bears a close relationship to the duration of heart failure, it is largest in essential hypertension when failure has been protracted; least enlarged in chronic nephritic hypertension when death is due to renal failure, or in those who die from apoplexy or from other non-cardiac causes (Harrison and Wood, 1949) Again, serial skiagrams may show little alteration in the manifest size of the heart for long periods in essential hypertension, yet gross enlargement may develop rapidly when failure occurs This is not merely a matter of cardiac dilatation, because heart weights show similar correlation. Slight to moderate left ventricular hypertrophy probably results from hypertension alone, according to its degree and duration, but gross enlargement, which usually involves the right ventricle as well as the left, is always due to protracted failure.

Moderate hypertrophy should be regarded as a compensatory change of structure which is beneficial· it helps the heart to perform more work (Dieckhoff, 1936)

Electrocardiography provides the most accurate means by which the degree of left ventricular enlargement and stress may be assessed. Leads facing the surface of the left ventricle, such as V5 and V6, show high voltage and slightly widened R waves, with depressed R-T segments and inverted T waves (fig 15.01) This fundamental pattern is reflected in right

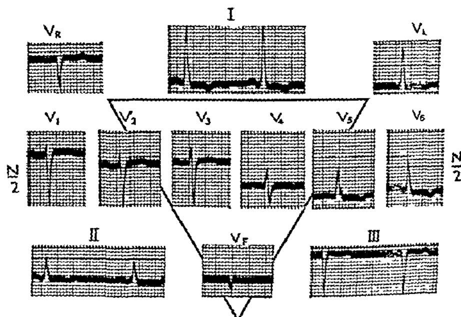


Fig 15 01—Electrocardiogram in a case of hypertensive heart disease (see text) The heart is electrically horizontal

ventricular surface leads, such as V1 and V2, as very small R waves and deep S waves, the S-T segment being elevated, and the T wave invariably upright The heart is usually electrically horizontal, left ventricular surface potentials being transmitted to the left arm, right ventricular surface potentials to the left leg Lead VL then resembles V5 and V6; lead VF resembles V1 Standard limb leads therefore show left axis deviation, lead 1 looking like VL and V5 or 6, lead 3 like VF and V1.

When the heart is rotated clockwise on its longitudinal axis (viewed from below), the anterior part of the inter-ventricular septum is displaced to the left, and the transition zone becomes V4 or even V5 (fig. 15 02), when the heart is rotated anti-clockwise, the transition zone moves to the right, and QR complexes or dominant R waves with inverted T waves may be found as far across as V2 (fig 15 03).

When the heart is electrically vertical, left ventricular surface potentials are transmitted to the left leg, right ventricular surface potentials to the left

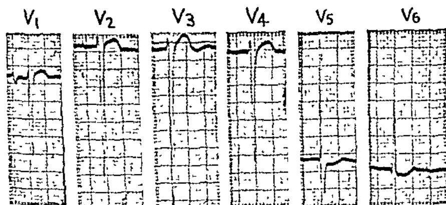


Fig 15 02—Electrocardiogram in a case of hypertensive heart disease with clockwise rotation about the longitudinal axis the transition zone is shifted to the left

VR I VL

V1 V2 V3 V4 V5 V6

II VF III

Fig 15 03—Electrocardiogram in a case of hypertensive heart disease with anti-clockwise rotation about the longitudinal axis the transition zone is shifted to the right

Fig 15 04—Electrocardiogram in a case of hypertensive heart disease The heart is electrically vertical (see text)

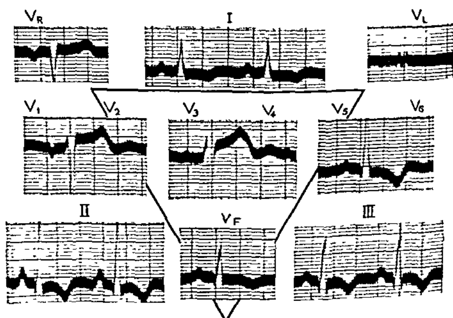


Fig. 15 05—Electrocardiogram showing concordant left ventricular preponderance due to a semi-vertical position of the heart.

arm. Lead VF then shows the tall R wave and inverted T, whilst lead VL has a prominent S wave. Standard leads may then show right axis deviation with inversion of the T wave in leads 2 and 3 (fig 15 04).

Concordant left ventricular preponderance in standard leads (fig 15.05) is due to a semi-vertical electrical position of the heart. Left ventricular surface potentials are transmitted to the left leg, and standard leads show high-voltage R waves and inversion of the T wave in all leads.

The higher and wider the R wave in lead V5–V6, and the deeper the S wave in lead V1, the bigger the left ventricle. The pattern may be distinguished from left bundle branch block by the presence of Q in lead V6 The cause of the R-T segment depression and the T wave inversion is less well understood· these changes may be associated with acute left ventricular stress without hypertrophy of the muscle, although they usually result from both; coronary disease is not responsible.

X-rays reveal left ventricular enlargement fairly well, but accurate measurement is difficult in obese subjects. The left border of the heart is not only displaced to the left, but is denser and more rounded than usual, and may sink deeply into the shadow of the diaphragm (fig 15.06a), whilst the point of opposing movement is displaced upwards. In the second oblique position the patient often has to be turned farther to the right in order to prevent the shadow of the left ventricle overlapping the spine, the increased bulk of the left ventricle is usually obvious (fig. 15.06b).

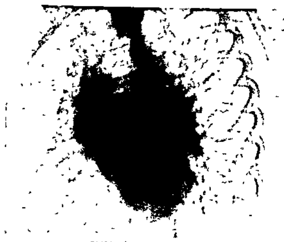
Hypertension also leads to unfolding of the aortic arch The ascending limb curves more forward and to the right, the descending more backward and to the left. In the antero-posterior view the aorta may thus appear widened, but it is only because the two limbs throw adjacent instead of superimposed shadows (fig 15.07a) Unfolding is best seen in the left anterior oblique position, especially with barium in the œsophagus, which is deflected back with it (fig. 15.07b), the abrupt angulation so caused occasionally produces dysphagia. In the first oblique position the œsophageal deflection may be almost as conspicuous (fig 15 07c) In this view, backward displacement of the œsophagus at left auricular level may be due to enlargement of the base of the left ventricle (fig 15 08)

The combination of left ventricular enlargement and unfolding of the aorta presents the characteristic appearance of two ovals set at right angles; another descriptive term is "boot-shaped" (this should not be confused with the "cœur en sabot", which compares the turned-up toe of the heart in Fallot's tetralogy with that of the wooden shoe commonly worn by Dutch peasants)

Angina pectoris occurs in 5 to 10 per cent of cases, and may be due to associated coronary atherosclerosis or to relative coronary insufficiency Pain may be typical, or it may tend to last longer than usual, even up to an hour or so, depending particularly upon transient rises of blood pressure such as occur, for example, in paroxysmal hypertension; strong emotion, e g fear or anger, and exposure to cold, may provoke such an attack.

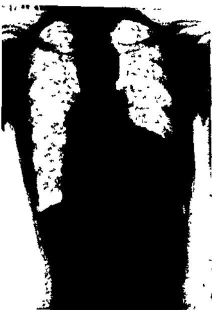


(a) Antero-posterior view the apex of the left ventricle is buried in the diaphragm



(b) Angiocardiogram in the second oblique position

Fig 15 06—Hypertensive heart disease showing left ventricular enlargement



(a) Antero-posterior view



(b) Left anterior oblique position

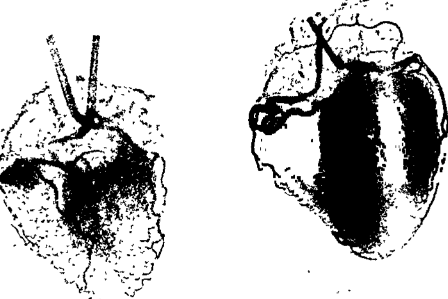
Fig 15 07—Skiagram of a case of hypertensive heart disease showing unfolding of the aortic arch



Fig 15 07 (c)—Right anterior oblique position



Fig 15 08—Right anterior oblique view of a case of hypertensive heart disease showing backward displacement of the œsophagus at left auricular level



(a)

(b)

Fig 15 09—Comparison of the coronary systems in a normal (a) and a hypertensive heart (b) The coronary vessels have been injected with a radio-opaque gel (see text)

6

87



(a)



(b)

Fig 15 10—Coronary systems of two cases of hypertensive heart disease with angina pectoris

(a) Showing occlusive coronary atherosclerosis (mixed case)

(b) Showing failure of the coronary vessels to enlarge with the heart

It will be remembered that the coronary blood flow depends upon the mean blood pressure, and upon the state of the coronary arteries During systole, the large extra-mural coronary vessels dilate, forming a tense elastic reservoir, the outflow being sealed by the intramural pressure The higher the systolic pressure, the greater this elastic reservoir. As the ventricles relax, blood flows through the intra-mural branches, influenced not only by the aortic diastolic pressure, but also by the elastic recoil of the superficial coronary arteries.

Autopsy studies indicate that the coronary blood flow in essential hypertension is considerably increased In figs. 15 09a and b the coronary systems of a normal and of a hypertensive heart are compared The vessels have been injected with a radio-opaque substance at the calculated mean pressure, and skiagrams have been taken at a fixed distance, so that comparative measurements are valid. The large and luxuriant coronary tree of the hypertensive case is typical of the series studied (Harrison and Wood, 1949). It is probable that the coronary flow behaves like the blood flow through skeletal muscle, and is usually increased in all forms of hypertension In cases of angina, however, skiagrams of the injected coronary vessels show either occlusive atherosclerosis (fig 15.10a) or a meagre coronary system which has failed to enlarge (fig. 15 10b).

Renal behaviour varies greatly according to the type of hypertension In the essential variety renal failure is rare, and when it does occur it is late, usually in patients over 70 years of age Minor degrees of renal involvement, however, are common Traces of albumin, and hyaline casts, are often found in the urine, due to glomerular fault, and diminished filtration may be revealed by inulin, creatinine, or urea clearance tests Tubular re-absorption may be impaired, resulting in polyuria and in diminished power of urinary concentration Nocturia may also be a feature.

In malignant hypertension there is always a fast race between renal failure, cardiac failure, and cerebral catastrophe. The end is sometimes a combination of all three. Nevertheless, despite the early occurrence of renal failure, it is rare for pronounced changes in renal function, or for conspicuous urinary findings, to precede the characteristic retinopathy (Wagener and Keith, 1924) The converse is true of nephritic hypertension Nephrosclerosis in malignant hypertension differs from that found in essential hypertension only in the presence of afferent glomerular arteriolar necrosis.

In chronic nephritis there is usually considerable evidence of renal damage at a time when the heart ...

polyuria, nocturia, and failure of urinary concentration

Cerebral manifestations occur sooner or later in about one-quarter of hypertensive cases *Cerebral hæmorrhage* is an ever-present danger, and

may at any time cut short the life of the patient. *Subarachnoid hæmorrhage* is by no means rare, congenital deficiencies in the media or elastica of certain arteries, particularly those forming the circle of Willis, with or without berry aneurysm, giving way to the high pressure *Cerebral thrombosis* may also occur, but depends more upon associated cerebral atherosclerosis

Hypertensive encephalopathy is characterised by attacks of severe headache, vomiting, coma or convulsions, lasting for hours, with or without transient localising signs. Its mechanism is obscure; but the customary treatment by dehydration is based on the belief that it is due to cerebral œdema, and this has limited pathological support (Scheinker, 1948) The diagnosis should never be made until cerebral or subarachnoid hæmorrhage has been excluded Sometimes careful subsequent examination of the central nervous system reveals some abnormality indicating a local vascular lesion.

Deterioration of higher cerebral function has already been mentioned, when severe it is usually due to associated atherosclerosis and ischæmia. Occasionally, however, multiple pin-point hæmorrhages, scattered widely throughout the frontal lobes, are found at autopsy, and provide adequate explanation for dementia

Hæmorrhages elsewhere are not uncommon and include epistaxis, hæmoptysis, and hæmatemesis. Whilst some local predisposing factor would seem probable, nothing significant is usually found Clinical diagnosis in such cases may be obscure at first, for hypertension may not be recognised owing to the fall of blood pressure which accompanies the hæmorrhage. Moreover, when hæmodilution is slow, so that the hæmoglobin or hæmatocrit level is but little reduced, the apparently normal blood pressure may lead to gross error of judgment concerning the size of the hæmorrhage Routine examination of the ocular fundi tends to prevent such mistakes

COURSE AND PROGNOSIS
(of persistent hypertension)

Perhaps the best follow-up studies in the literature are those by Janeway (1913), Blackford, Bowers and Baker (1930), and Bechgaard (1946) Janeway found that one-half of 458 patients were dead within five years, and three-quarters within ten years of the onset of symptoms. Blackford, Bowers and Baker reported a 50 per cent mortality (70 per cent of the men; 39 per cent of the women) amongst 222 cases within five to eleven years. Of Bechgaard's 1,000 patients, 41 per cent of the men and 22 4 per cent of the women were dead within five to ten years. The better outlook in women was emphasised in all three articles Bechgaard found the mortality rate of hypertensive men was 2 9 times, and women 1.4 times, that of the general population, and was similar in all age groups (excluding renal cases).

Apart from sex the chief factors affecting prognosis include the type of hypertension, the degree of retinopathy, the height of the blood pressure,

and the state of the heart. The natural outlook in malignant hypertension is uniformly bad, few cases surviving more than one or two years Chronic nephritic hypertension also has a grave prognosis, the mortality rate being about nine times that of essential hypertension This is partly because renal hypertension is often a late manifestation of chronic kidney disease—hence the frequency of a normal-sized heart in this group.

Wagener and Keith (1939) correlated life expectancy with changes in the ocular fundi; they followed the course of 209 patients for five to nine years The survival rate according to whether retinal changes were mild, moderate, severe or gross was 80 per cent, 35 per cent, 9 per cent, and nil, respectively When retinopathy was gross and included papillœdema, 80 per cent died within one year.

The height of the blood pressure matters little so long as it remains within the slight or moderate grade, i e under 130 mm Hg diastolic, but above this level it is always serious.

Cardiac behaviour in hypertension is determined by the amount of extra work involved, and by the ability of the heart to cope with it, it is chiefly influenced by the rapidity of hypertensive development, by the size and strength of the left ventricle, and by the efficiency of the coronary blood flow. The best defence is put up by a placid patient of voluntary or enforced sedentary habits and occupation, who has a naturally strong left ventricle with a good coronary blood flow, when hypertension is neither too severe nor too sudden. Under such circumstances the heart enlarges but little over the years, failure is indefinitely deferred, and the patient remains free from cardiac symptoms. The worst defence, leading to rapid failure, and perhaps to early death, occurs in an excitable individual of active physical habits and strenuous occupation, who tries to cope with a rapidly developing and extreme hypertension with an unprepared left ventricle indifferently nourished by a mean coronary system

Evidence of any cardiac abnormality, e g diminished cardiac reserve, angina pectoris, enlargement, or electrocardiographic changes, at once doubles or trebles the mortality rate (Bechgaard, 1946) Inversion of the T wave in left ventricular surface leads or their equivalent is particularly grave, at least 60 per cent of such cases being dead in an average of eight months from the time of its discovery (Rykert and Hepburn, 1935) Auricular fibrillation means death within two years in 80 per cent of cases (Rothstadt, 1938)

Hypertensive heart failure is characteristically left ventricular at first and limits life-expectancy to about eighteen months Systemic congestion follows sooner or later Several congestive attacks usually occur, each responding less satisfactorily to treatment than its predecessor The patient finally sinks into a stuporose condition with chronic venous congestion, hepatic engorgement and dependent dropsy; the blood pressure falls, Cheyne-Stokes breathing develops, and death comes slowly. Heart disease is responsible for death in 33 per cent (Janeway, 1913) to 55 per cent (Bell

and Clawson, 1928) of hypertensive cases; stroke in 7.2 per cent (Paullin *et al.*, 1927) to 16 per cent (Bechgaard, 1946); uræmia in 10 per cent (Bechgaard, 1946).

The average life expectancy in uncomplicated benign hypertension of slight or moderate grade is about fifteen years (Fahr, 1928). Obese subjects do as well or better than those with normal weight, probably because their blood pressures are not as high as they seem, possibly because of benefits derived from weight reduction. Spontaneous recovery occurred in 5 4 per cent of Bechgaard's series (2 per cent of the women; 13 per cent of the men), but in none of those seen by Blackford, Bowers and Baker. After five to ten years 58 per cent of Bechgaard's cases were free from symptoms or only slightly inconvenienced.

Only about 0 2 per cent of cases of simple high blood pressure develop malignant hypertension, but 8 per cent of cases of chronic pyelonephritis do so.

TREATMENT

It must be said at once that as yet there is no satisfactory treatment for essential or for malignant hypertension, when nephritic hypertension is due to a unilateral lesion such as chronic pyelonephritis, nephrectomy may be curative, but otherwise it can be little influenced The hypertension of Cushing's syndrome responds to removal of the offending tumour, and that due to coarctation of the aorta to surgical repair. When hypertension is associated with unilateral renal disease, a causal relationship cannot always be assumed, before advising nephrectomy it is well to make sure

as to have made it ischæmic and so to have established a vicious circle (Wilson and Byron, 1941)

For essential hypertension there are four main lines of treatment: (1) conservative, (2) the low sodium or rice diet, (3) thiocyanates, (4) lumbo-dorsal sympathectomy.

Conservative. When the grade of hypertension is mild or moderate, and when the prognosis is judged to be good on criteria previously outlined, radical medical or surgical treatment is hardly justified; but this does not mean that nothing else need be done. Conservative treatment seeks to correct adverse factors and to prevent complications or deterioration

If circumstances permit, it is a good plan to begin treatment by putting the patient to bed, and to keep him there until the blood pressure has

pressure to bed rest gives useful diagnostic and prognostic information,

innocent labile types falling quickly to normal, nephritic and malignant hypertension responding least

Patients should then be advised to live at a lower tempo. they should learn to refuse extra commitments and gradually to relinquish the least important or most irksome of those they already have; they should keep all Saturday and Sunday free for relaxation, should have at least nine hours rest in bed every night, and should insist on proper holidays each year, preferably six weeks. Long working hours, heavy mental or physical stress, and the general rush, hurry and struggle of modern life must be avoided or reduced. Occupation may require modification, but it is rarely practicable to change it radically, for the patients are generally too old. Sudden effort, especially in the cold or after a heavy meal, should be avoided, straining at stool should be prevented by regular habits, and if necessary by the use of liquid paraffin.

Mental relaxation may be impossible without sedatives or psychiatric help. Phenobarbitone, ½ to 1 grain (32 to 64 mg.) t d s may be prescribed at times of unavoidable anxiety, alternated with potassium bromide, 5 to 10 grains (0.32 to 0 65 G.) t.d s. Psychiatric help is invaluable, not necessarily from a psychiatrist, but by any experienced physician with the requisite knowledge Many of the symptoms ascribed to hypertension are more often due to anxiety; moreover, hypertensives usually have hyper-reactions to anxiety in the sense that their blood pressures rise unduly (Hines, 1940) Details of psychiatric treatment are given on page 543

Symptoms attributed to hypertension at the menopause may respond to stilbœstrol, 1 to 3 mg. daily, although the blood pressure does not fall, an associated anxiety state is also common at this time

Obese patients tend to do well on a weight-reducing diet This is not merely because they lose weight, but because small meals are beneficial to hypertensives. One day's bed rest with semi-starvation per week, diet then being limited to fresh fruit, fruit juice and water only, may be most helpful, or such a régime may be instituted at less frequent intervals when the patient feels the need of it.

The use of harmless blood pressure reducing drugs other than sedatives is no part of conservative treatment, for none substantiates the claims made for it (Evans and Loughnan, 1939) Thiocyanate will be considered later

Venesection has been advocated in the past and is still practised from time to time It is only justified in phlethoric cases associated with polycythæmia. In essential hypertension its effect is fleeting, the blood pressure often regaining its previous level within twenty-four hours. In malignant hypertension and in chronic nephritis venesection is contra-indicated, for some degree of anæmia is usually present in both conditions

Low sodium diet. A low sodium diet consisting of soya beans, peanut flour, cooked potatoes, rice, starch and gelatine lowered the blood pressure in experimental hypertension in rats (Grollman and Harrison, 1945) Subsequent clinical studies have shown that a similar diet may reduce the

blood pressure substantially in essential human hypertension (Grollman, 1945). A low sodium diet is described in detail on page 185. The rice diet (Kempner, 1946) consists of rice cooked in unsalted water, fruit in any form, and sugar; fruit juice and fluids are given freely. This contains less than 0.5 G. of sodium per day.

The blood pressure is said to fall significantly (average 45/25) in about 60 per cent of cases, and there is usually a loss in weight of about 7 lb (3 kg.). As soon as such benefit is demonstrated, the diet may be modified by adding meat, vegetables, and other foods listed on page 186. It is not practicable to maintain the initial rigid diet for long, nor to maintain the daily sodium intake below 1 G for more than a few weeks.

Treatment of this kind, or by semi-starvation, is useful to check hypertensive crises or to lower the blood pressure quickly when it is found to be dangerously high. The value of the modified diet in maintaining pressures at lower levels is less well established.

Thiocyanates Thiocyanate was originally introduced as a hypotensive agent by Treupel and Edinger (1900), but gained no immediate favour in view of the difficulty experienced in avoiding serious toxic symptoms. Considerable interest has been taken in the drug, however, since Barker (1936) showed that the dose could be properly controlled if the thiocyanate blood level was estimated weekly The normal serum thiocyanate ranges between 0 and 2 77 mg. per cent and is not altered in hypertension (Connell, Wharton and Robinson, 1946). Levels above 15 mg. per cent are dangerous, and those between 12 and 15 mg per cent are risky Toxic symptoms include weakness, anorexia, indigestion, nausea, vomiting, limb pains, impotence, purpura, dermatitis, goitre, thrombophlebitis, mental lethargy and confusion In fatal cases dysarthria, verbal aphasia, convulsions, hallucinations, delirium and mania have usually preceded death by three to nineteen days (Del Solar *et al.*, 1945). Progressive anæmia and emaciation have been attributed to chronic poisoning after five to ten years' continuous therapy (Wald, Lindberg and Barker, 1939).

The potassium salt is given by mouth in initial doses of 2 to 3 grains (0.13 to 0.2 G) three times daily after meals. The serum thiocyanate is measured on the seventh day and then at weekly intervals, subsequent dosage being regulated as follows.

Thiocyanate level	*Dosage recommended*
Under 5 mg. per cent .	. 2 to 3 grains (0 13 to 0.2 G.) t.d.s
5 to 7 ,, ,, .	. 1.5 grains (0.1 G.) t.d.s.
7 to 10 ,, ,, .	. 1 grain (64 mg.) t d.s.
Over 10 ,, ,, .	. Stop drug for one week

The lowest blood level compatible with a satisfactory hypotensive effect should be maintained for three to six months. Further courses may be given as desired.

The drug is said to be unsafe in patients who are over 60 years old, who have had cerebral or other thrombosis, or who have poor renal function, but Watkinson and Evans (1947) observed no ill-effect in fifteen patients over 60, nor in sixteen cases of malignant or chronic nephritic hypertension.

Thiocyanates have been particularly recommended for labile hypertensives who complain of headache and giddiness (Hines, 1946), but they have also been used for severe or gross cases unsuitable for lumbo-dorsal sympathectomy, and as an adjunct to surgical treatment.

Clinical benefit associated with a significant fall of blood pressure has been claimed in about 60 per cent of cases (Watkinson and Evans, 1947) This figure is not impressive when it is recollected that Bechgaard found that 58 per cent of 1,000 persistent hypertensives did well without treatment. Carefully controlled observations such as those by Rusken and McKinley (1947) are more convincing, and throw considerable doubt on the efficacy of thiocyanates. It is well to remember that Pauli (1903), who is usually credited with introducing thiocyanate for the treatment of hypertension, actually used the drug in the hope that it would prove superior to bromide in allaying anxiety symptoms, and reported singular success in this respect The effect of sedation on hypertension is well known, and if thiocyanate merely acts in this way, it should be abandoned in favour of less toxic substances.

Lumbo-dorsal sympathectomy In recent years numerous attempts have been made to lower the blood pressure by surgical means The only operation which has proved eminently successful is nephrectomy in those relatively rare cases in which hypertension is due to unilateral renal disease, such as chronic pyelonephritis Of other surgical measures the best known is lumbo-dorsal sympathectomy as elaborated by Smithwick (1940) This consists of bilateral resection of the whole sympathetic chain from D8 to L2, including preganglionic fibres, ganglia, and splanchnic nerves It has proved superior to Adson's subdiaphragmatic splanchnicectomy with resection of the first and second lumbar ganglia (Allen and Adson, 1940), and to Peet's supradiaphragmatic splanchnicectomy with lower dorsal ganglionectomy (Peet, Woods and Braden, 1940). The object is to release as much vasoconstrictor tone as possible, to prevent renal cortical vasoconstriction, to produce postural hypotension, and, of course, to lower the basal blood pressure if possible With these aims there has been an increasing tendency to extend Smithwick's operation, and a number of surgeons, e g Grimson (1947) and Boyd (1948), now favour either total or subtotal paravertebral sympathectomy, splanchnicectomy and cœliac ganglionectomy

The results of these various procedures have been fair The operative mortality has averaged 3 9 per cent, but about 25 per cent have died during the period of post-operative observation There is no doubt that headache, dizziness and other symptoms may be alleviated, that the blood pressure may be lowered, the electrocardiogram improved, the heart size reduced,

... means objective improve- ... le in about 60 per cent ... by different workers are ... different criteria

Early persistent hypertension of moderate ... ative vascular changes have set in, should respond best, but the outlook is then sufficiently good to restrain most physicians from advising surgical treatment, yet if left until serious complications have arisen, it may be too late This is the crux of the problem The best compromise may be to advise lumbo-dorsal or more extensive sympathectomy in relatively young hypertensive subjects (under 50), whose pressures are known to be rising, or whose casual diastolic pressures tend to exceed 130 mm. Hg after proper medical measures have been instituted.

It is not easy to predict which cases will do well The sedation test is perhaps as good as any; it consists of giving sodium amytal, 3 grains (0 2 G), hourly, for three doses, while the blood pressure is recorded every hour. The greater the drop, the more likely is the operation to be successful

Surgical treatment should not be undertaken if the patient is over 50 years old, if renal function is seriously impaired, if there is congestive heart failure, or if there has been myocardial infarction. Angina pectoris is no deterrent, nor is a previous stroke; early left ventricular failure that responds well to medical treatment is likewise no contraindication Obese subjects are technically more difficult and are probably better avoided, not only on that account, but also because they may do fairly well if treated medically. Women are often preferred to men because they usually do better, but it should be remembered that the prognosis is twice as good in women if untreated.

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CHAPTER XVI

PULMONARY EMBOLISM

PULMONARY embolism may cause acute or subacute pulmonary heart disease, sudden death from reflex ventricular fibrillation or cardiac standstill, pulmonary infarction, or no ill-effects Emboli may be single or multiple, infected or sterile. They are usually attributable to mobile venous thrombi originating in the legs, but are occasionally due to fat, air, foreign body, or to fragments of some remote malignant tumour.

THROMBO-EMBOLISM

General incidence Massive pulmonary embolism is directly or chiefly responsible for about 3 per cent of all hospital deaths, published figures ranging from 2 to 6 5 per cent as shown below:

Author	*Number of necropsies*	*Incidence of fatal pulmonary embolism, per cent*
Belt (1934)	567	6.5
Collins (1936)	10,940	2.07
Pilcher (1939)	2,861	4.5
Hampton and Castleman (1940)	3,500	3.5
McCartney (1945)	25,771	2 62
Crutcher (1948)	2,580	2,14

The actual incidence of clinical thrombo-embolism among all hospital patients is difficult to assess, but appears to be about 1 per cent in post-operative cases (Nygaard *et al.*, 1940–41), and is believed to be equally frequent in medical, obstetrical and gynæcological wards (Belt, 1939)

ETIOLOGY

Thrombo-embolism results from the breaking away of a blood clot, formed either in the right side of the heart or in the systemic venous system.

Intracardiac thrombosis. Clots may form in the heart in cases of mitral stenosis, auricular fibrillation, congestive failure, myocardial infarction, bacterial endocarditis, and Fiedler's carditis. Damaged endocardium, slowing of the blood flow, and backwater eddies in dilated chambers are important contributory factors In mitral stenosis, clots are more likely to form

in the left than in the right auricle unless there is congestive heart failure. Myocardial infarction practically always affects the left ventricle, and as mural thrombi are limited to the area of devitalised tissue, emboli from the heart are usually systemic; exceptions are associated with septal infarction Bacterial endocarditis is only a source of pulmonary emboli when it affects the pulmonary or tricuspid valve, a ventricular septal defect, or a patent ductus arteriosus; infarcts so produced are apt to be small and frequent, the clinical course resembling subacute or chronic hæmorrhagic bronchopneumonia Fiedler's carditis is mentioned because it is sometimes complicated by mural thrombi, which may break away and cause repeated hæmoptysis.

Venous thrombosis. Intracardiac thrombosis, however, accounts for only about 10 per cent of pulmonary emboli (Belt, 1939), the remainder, including the majority of those associated with mitral stenosis, auricular fibrillation, myocardial infarction and congestive heart failure being due to venous thrombosis, particularly in the legs Such emboli are common. Belt (1939) found them in 6 per cent of 1,990 consecutive necropsies, and as often in medical as in surgical cases They were directly responsible for death in 22 instances (1 1 per cent) and a contributory factor in approximately 70 (3 5 per cent).

The chief causes of venous thrombosis may be listed under three main headings:

1 *Local venous injury.*
   (*a*) Inflammatory—as in thrombophlebitis
   (*b*) Chemical—from the injection of irritant solutions.
   (*c*) Traumatic—as in fractures.
   (*d*) Infiltrative—as in cancer
2. *Slowing of the venous blood flow*
   (*a*) By local obstruction—as by tight bandaging, immobilisation in an unfavourable posture, or space-filling lesions (including obesity)
   (*b*) As a whole—as in heart failure
3. *Increased clotting tendency of the blood*
   (*a*) Post-operative, post-traumatic and puerperal states.
   (*b*) Polycythæmia and hæmoconcentration
   (*c*) Associated *with tissue breakdown, e g carcinoma of the* stomach, myocardial infarction
   (*d*) Certain fevers, e g typhoid

The mechanism of intravascular clotting is a complicated process and is not yet fully understood Its discussion is beyond the scope of this work, and the reader is referred to the excellent monograph by Nygaard (1941)

Thrombophlebitis is often said to be less dangerous than simple phlebothrombosis; but this is doubtful, for the former is less frequent but more

easily diagnosed, whilst the latter is common but apt to be overlooked, so that the percentage incidence of embolism is likely to appear higher in phlebothrombosis Fatal pulmonary embolism follows the injection treatment of varicose veins in 0.05 per cent of cases (Westerborn, 1937), and the operative treatment in 0 4 per cent (Westerborn, 1937; McPheeters and Rice, 1928).

Fractures, particularly of the legs or pelvis, may cause thrombo-embolism on account of injury to veins, immobilisation, and post-traumatic acceleration of the clotting time, they may also give rise to fat embolism Malignant neoplasms, especially carcinoma of the stomach, may be responsible for thrombo-embolism as a result of venous infiltration, mechanical venous obstruction, and shortening of the clotting time (owing to tissue necrosis) They may also give rise to malignant cellular emboli.

The most common cause of phlebothrombosis is immobilisation in bed, especially in obese subjects over 40 years of age Of 229 cases of fatal post-operative pulmonary embolism, Prettin (1936) found the average weight in women was 11 kg. above normal, and in men 4.2 kg In a series at the Mayo clinic, 93 per cent of fatal post-operative pulmonary emboli occurred in patients over 40 years of age (Barnes, 1937).

Congestive heart failure encourages phlebothrombosis because the circulation is slowed When the cardiac output remains elevated or is less reduced than usual, as in failure from the hyperkinetic circulatory states, thrombosis is rare. Congestive failure due to mitral stenosis or to myocardial infarction is particularly dangerous. Eppinger and Kennedy (1938) found that pulmonary embolism was the direct cause of death in 6.5 per cent of 200 fatal cases of coronary thrombosis, and a contributory cause in 32 7 per cent of those with congestive failure The clotting time appears to shorten after myocardial infarction, perhaps owing to the products of tissue necrosis. The clotting time also appears to be shortened by digitalis (Massie *et al*, 1944) and by the organic mercurial diuretics (Macht, 1946)

Almost any major surgical procedure may result in thrombo-embolism, but abdominal and pelvic operations carry the highest embolic risk Responsible factors include post-operative reduction of the clotting time (maximum at the tenth day), and immobilisation Child-birth incurs a similar risk for similar reasons McCartney (1945) found that pulmonary embolism was directly responsible for 5.28 per cent of obstetrical fatalities, and for 5.1 per cent of post-operative deaths.

HÆMODYNAMICS AND PATHOLOGY

Acute pulmonary heart disease. Experiments in which the pulmonary arteries have been occluded in varying degree by ligature, or by artificial emboli, have shown that it is necessary to obstruct about 60 to 85 per cent of their total cross-section before the systemic blood pressure falls or before signs of right ventricular failure can be detected, and between 85 and 100 per cent before death ensues (Gibbon, Hopkinson and Churchill, 1932) It

is thus possible to undertake unilateral pneumonectomy without embarrassing the circulation (Barnes, 1941). In accord with these facts the majority of pulmonary emboli cause no cardiac disturbance; but when a large embolus lodges at the bifurcation of the main pulmonary artery, or when multiple emboli block more than two-thirds of the more distal trunks, the circulation is impeded and the left ventricular output falls This is the condition known as massive pulmonary embolism; its effect upon the heart is acute pulmonary heart disease. Compensatory adjustments include vasoconstriction which combats the falling blood pressure, elevation of the right ventricular pressure which helps to squeeze blood past the obstruction, and elevation of the venous pressure which serves to encourage the right ventricle It is as yet uncertain whether that chamber usually becomes overloaded or not. In cases which recover, the embolus is gradually packed to the side of the vessels, where it becomes organised, and finally shrinks to a mere thread. Infarction of the lung does not necessarily occur, because sufficient blood may pass through to nourish the tissues

Subacute cases may occur in which repeated small emboli gradually block the pulmonary circulation over a period of weeks or months (Belt, 1939).

Pulmonary infarction. When an embolus lodges distally in a relatively small arterial trunk, there is no rise of pressure in the pulmonary artery, blood is not squeezed past the obstruction, and the block is complete, infarction of that part of the lung supplied by the occluded vessel follows (unless the collateral circulation is sufficient to nourish the ischæmic area) Of course, such an event is likely to complicate massive pulmonary embolism, and does so in 62 per cent of cases (Belt, 1934), but it is a complication, and not an essential part of the picture. Admittedly, experimental pulmonary embolism does not cause infarction in animals unless the circulation is otherwise impaired (Karsner and Ash, 1912), but no such condition appears to be necessary in clinical medicine. Infarcts of the lung are hæmorrhagic because blood from the bronchial arteries exudes into the devitalised area If this second source of nutrition is adequate for the needs of the tissue, infarction does not occur When the hæmorrhagic zone reaches the surface of the lung, a sero-fibrinous pleural reaction develops pain may be severe as in any other pleurisy, effusion is common and is usually blood-stained

Pulmonary infarcts are nearly always embolic in origin (Virchow, 1856), very few are due to primary pulmonary thrombosis, and they rarely complicate idiopathic pulmonary hypertension or Fallot's tetralogy, two diseases in which primary thrombosis is relatively common

CLINICAL FEATURES

Massive pulmonary embolism In a typical dramatic attack the patient feels as if he had been struck in the centre of the chest, and rapidly becomes faint, grey, cold, clammy and breathless Central sternal pain may be indis-

MASSIVE PULMONARY EMBOLISM

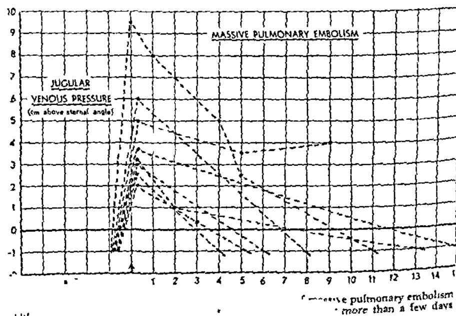
BLOOD PRESSURE

200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50

Died
Died
Died
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DAYS 0 1 2 3 4 5 6 7 8 9 10 11

Fig 16 01—Behaviour of the blood pressure in 9 *cases of* massive pulmonary embolism There is invariably a profound initial drop In the group shown, those with *relatively* high blood pressures previously recovered, *whereas* those with relatively low pressures previously died



...e pulmonary embolism
more than a few days

tinguishable from that of acute myocardial infarction Consciousness may be lost. Peripheral cyanosis is evident in the ears, lips and nail-beds, but elsewhere pallor is usually more noticeable. Sweating is commonly profuse The pulse is thready and rapid, or may be imperceptible, the blood pressure is low or immeasurable (fig. 16 01). The jugular venous pressure is invariably raised (fig 16 02) and the liver may be palpable; cardiac œdema is not seen in acute cases, but may occur later in the subacute form Examination of the lungs may reveal nothing abnormal The heart sounds are usually soft, although the second [illegible]

bolus have been described by McGinn and White (1935), and by Churchill (1934), respectively. The Graham Steele murmur of functional pulmonary incompetence has been heard (White and Brenner, 1933) Occasionally a pericardial friction rub develops over the base of the distended pulmonary artery (White, 1937).

Rarely, patients die abruptly at the onset, presumably from reflex cardiac inhibition or ventricular fibrillation, such deaths being preventable by atropine in animals and being independent of the size of the embolus (Scherf and Schönbrunner, 1937) The great majority, however, survive the initial insult; but about one-third die subsequently from circulatory obstruction, approximately 10 per cent within 10 minutes, 30 per cent within an hour, and 60 per cent in a matter of hours or days (de Takats and Fowler, 1945). On the other hand, about two-thirds recover—within hours, days or weeks. Throughout this anxious period there is a 25 per cent risk of another, and perhaps fatal, embolus.

Massive pulmonary embolism, however, is not always dramatic, and mild cases are easily overlooked Passing tightness of the chest, fleeting unexplained breathlessness, transient faintness, or a symptomless rise of systemic venous pressure may be the sole manifestation of an event that brought death very close

Subacute cases may pass gradually into congestive heart failure without a single incident suggesting embolism the clinical features of these rare cases resemble those of primary hypertensive pulmonary heart disease

It should be noted that "calling for the bed-pan and falling back dead" is not specially correlated with pulmonary embolism The phenomenon appears to be associated with impending death from ventricular fibrillation or asystole, and may occur as a tragic climax to many forms of heart disease, including aortic stenosis and myocardial infarction The colonic disturbance may be a vagal manifestation. Abrupt death from pulmonary embolism, preceded or not by a call to stool, is rare as already mentioned

The diagnosis of acute right ventricular stress may be proved electrocardiographically (fig. 16 03) Limb leads show sinus tachycardia, a constant S wave in lead 1, a frequent Q wave in lead 3, inversion of T_3, flattening or slight inversion of T_2, and rather low voltage (Barnes, 1937)

Occasionally P_2 becomes tall and sharp (Wood, 1948) These appearances are not unlike those of posterior myocardial infarction, although an absent S_1, conspicuous Q_2, and elevation of the R-T segment in lead 3 should be sufficient to distinguish the latter in standard leads Again, Q_3 in cases of

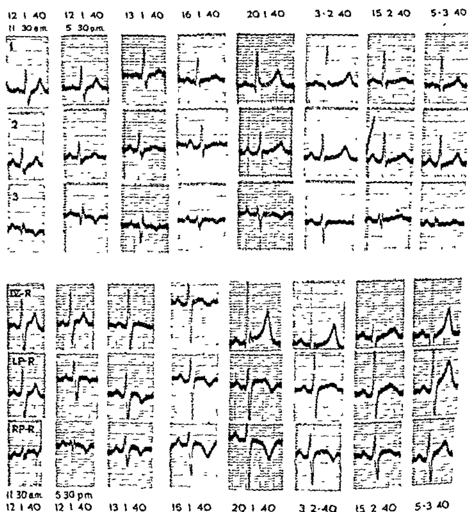


Fig 16 03—Electrocardiogram showing the characteristic appearances associated with massive pulmonary embolism (lead IV-R = CR4, LP-R = CR2–3, RP-R = CR1).

massive pulmonary embolism is caused by cardiac rotation, and is not seen in lead VF In multiple chest leads appearances are equally characteristic (Wood, 1941). the T wave is nearly always inverted in leads V1–3 over the right ventricle, sometimes in V4 and occasionally even in V5 (fig. 16 03); and clockwise rotation or displacement of the interventricular septum to the left brings the RS pattern round as far as V5 or even V6. There are no pathological Q waves and the RS-T segment is not deviated from the base-

ine; but in about 15 per cent of cases there is transient right bundle branch block (fig. 16 04) These changes are not immediate, but develop within a few hours, and are usually maximum within one to three days Recovery is relatively slow, three to six weeks elapsing before the T wave is finally upright again in leads V1 or V2.

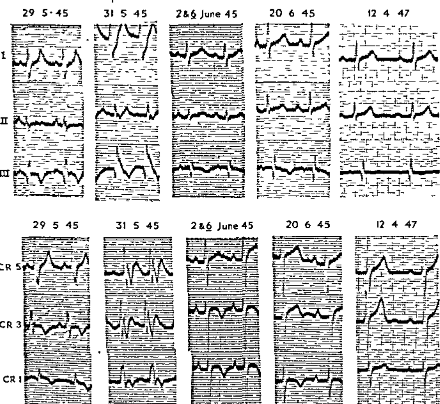


Fig 16 04—Electrocardiogram showing transient right bundle branch block in a case of massive pulmonary embolism

The electrocardiographic pattern has been variously attributed to reflex coronary spasm (Scherf and Boyd, 1939), to interference with the coronary blood flow through the right ventricle owing to the combined effect of a low aortic and high right ventricular pressure (Durant, Long and Oppenheimer, 1947), and to right ventricular stress (Wood, 1941) There is no proof of coronary spasm, and, although usually ascribed to a vagal reflex, the electrocardiographic pattern is unaltered by vagal section in dogs (Malinow, Katz and Kondo, 1946) In experimental air embolism in dogs, Durant, Long and Oppenh...

of right ve

frequency



Fig 16 05—Skiagram showing a small pulmonary infarct at the right base with a little hæmorrhagic effusion

On the other hand, remarkably similar changes are found in any condition giving rise to right ventricular stress

Pulmonary infarction. When an embolus lodges in a small or moderate sized pulmonary artery there are no immediate symptoms or signs. Within a variable time, however, impossible to determine clinically, a sudden pleural pain may signal the accident. Hæmoptysis may precede or follow the pain, may not occur at all, or may occur without pain. Coincident with these events, and especially if there is pleurisy, the respiratory rate rises and fever develops Examination of the chest reveals little at first, except perhaps pleural friction, but within a day or two the percussion note may become impaired, the breath sounds diminished, and râles may be heard, sometimes there are frank signs of consolidation or of fluid. When the diagnosis is in doubt, a specimen of this fluid should be obtained, for it is hæmorrhagic in most cases of infarction A skiagram is also helpful, the cone-shaped infarct casting a triangular, egg-shaped, or rounded shadow, according to its lateral, oblique, or antero-posterior lie (fig. 16 05) Unfortunately, the characteristic appearance is often obscured by the obliterating shadow of fluid. When embolism occurs without infarction, skiagrams may show a segmental area of increased translucency owing to the absence of vascular shadows in the ischæmic area (Shapiro and Rigler, 1948).

Pain, hæmoptysis, fever and tachypnœa may last a week or two, but the patient does not look or feel seriously ill unless the primary disease makes him so. Moderate leucocytosis and a rapid erythrocyte sedimentation rate are the rule, the former lasting a few days, the latter several weeks, as with cardiac infarction.

Whilst the above description applies to most cases, it should be added that infarcts may be clinically silent, and are often only discovered at necropsy. In other cases, secondary infection complicates the picture, or the embolus may be infected from the start; pulmonary abscess or empyema may then develop

Venous thrombosis. In all cases of suspected pulmonary embolism a search should be made for the source As previously stated, this is commonly phlebothrombosis in the legs. It usually begins in the calf, where there may be deep muscle tenderness, or pain on dorsiflexing the foot (Homans' sign) Superficial thrombosis in the long saphenous vein may be felt as a solid cord, and is usually tender. With thrombo-phlebitis the overlying skin is hot, red, indurated and painful. Extension to the femoral vein causes a conspicuous rise of skin temperature in the affected limb, a most useful sign of serious phlebothrombosis; œdema also occurs in many cases, but is less constant

PROGNOSIS

It is not easy to assess the true mortality rate in thrombo-embolism, for many mild cases are overlooked, but in a series of twenty clinically recognised cases of massive pulmonary embolism seen by the author, six died.

In necropsy material, about two-thirds of all pulmonary emboli are major, involving more than 50 per cent of the cross-section of the pulmonary arteries (Belt, 1939), but it is naturally the more severe ones that are seen at necropsy. From evidence of this kind it is estimated that nearly two-thirds of all cases of massive pulmonary embolism recover, and that less than a third of clinical thrombo-emboli are massive, this gives a total mortality rate of about 10 per cent.

TREATMENT

Prophylaxis is most important, and should be directed towards accelerating the venous circulation in the legs and preventing the clotting process in bed-ridden patients.

Breathing exercises, massage, frequent changes of position, active movements of the legs for specified times every day, prevention of dehydration, and limitation of morphine, are simple, logical, and effective measures Heart failure should be treated quickly and adequately. Rest in bed should never be prolonged unnecessarily

Heparin is the quickest and safest anticoagulant; but it is too expensive for routine prophylactic use. It should certainly be employed, however, as soon as the thrombo-embolic state is recognised, for 23 per cent are multiple (Nygaard *et al*, 1940–41) and not more than a quarter of cases of massive pulmonary embolism are fatal at the first insult (de Takats and Fowler, 1945) Heparin may be given intravenously in doses of 50 mg. (5,000 units) four- to six-hourly, by continuous intravenous drip in doses of 150 to 300 mg. daily (50 to 100 mg. to a pint of normal saline), or intramuscularly combined with 2 ml. of 2 per cent procaine) in doses of 150 mg. twice daily. The last route is simple and effective. Procaine prevents pain and bruising is rarely serious The dose of heparin should be regulated so that the clotting time is maintained at about two to three times the normal [illegible] rose [illegible] ent)

Dicoumarol, the cause of hæmorrhagic sweet-clover disease of cattle (Link, 1943) is a cheaper and equally effective anticoagulant, but its action is delayed for forty-eight to seventy-two hours, and it is more difficult to control. It is given by mouth in a single dose each day, beginning with 300 mg on the first day, 200 mg on the second, and 100 mg. thereafter, until the prothrombin activity of the blood approaches the desired level of 30 to 50 per cent of normal (de Takats and Fowler, 1945) The dose is then reduced to 50 to 100 mg, and is given daily or at less frequent intervals according to the prothrombin time. The latter must be measured daily during the first ten days of treatment, then on alternate days, for the effects of the drug cannot be accurately predicted, and fatal hæmorrhage may occur following an overdose. Dicoumarol should be temporarily discontinued if there is hæmaturia, melæna, or bleeding from other sites,

whatever the prothrombin time. Alarming hæmorrhage calls for fresh blood transfusion and repeated injections of 100 to 200 mg of vitamin K intravenously (Barker *et al.*, 1945)

In view of the delayed effect of dicoumarol, heparin is usually given as well during the first forty-eight to seventy-two hours It is customary to continue dicoumarol for a month. With this treatment the post-operative mortality rate from massive pulmonary embolism in cases specially selected as thrombo-embolic risks has been reduced from perhaps 5 per cent to 0 1 to 1.0 per cent (Barker *et al*, 1945; Wright, 1946).

Tromexan, bis-3, 3′-(4-oxycoumarinyl) ethyl acetate, is likely to replace dicoumarol, for it acts more quickly and is easier to control. the initial dose is 0.9 to 1 2 G., and the maintainance dose 0 3 to 0 6 G daily (Burt, Wright and Kubik, 1949).

Bilateral ligation of the femoral or common iliac veins or ligation of the inferior vena cava has been received with less enthusiasm; but it may be a life-saving procedure where anti-coagulants are contraindicated.

Treatment of acute pulmonary cardiopathy Relatively mild cases recover spontaneously and require no special treatment The majority of those clinically recognised, however, are seriously ill, and require urgent attention The objectives are to encourage the embolus to move on, or to be packed against the wall of the vessel, and to support the right ventricle Eupavarine, 1 mg. intravenously, has been recommended, but it is doubtful whether it really dilates the main pulmonary artery or its larger branches To encourage packing, the art is to play for time, if the patient can be kept alive (and every hour counts in his favour) progressive packing takes place automatically. To this end the vital centres must be supported as the blood pressure is low, the patient should be nursed flat in order to encourage the cerebral circulation, oxygen, with the flow-meter adjusted to six or seven litres per minute, should be administered continuously through a B L B mask, or if possible the patient should be nursed in an oxygen tent, for the arterial oxygen saturation is often diminished, respiratory failure may temporarily respond to 0 48 G. of aminophylline, or to 10 ml of coramine, intravenously. Until recently it has been assumed that venesection and other venous pressure lowering agents would help the right ventricle, but this is doubtful, for the raised venous pressure may be beneficial (fig 16.06) (Wood, 1947) Strophanthin, 0 5 to 1 0 mg intravenously, helps to support the right ventricle.

The Trendelenburg operation—exposure of the pulmonary artery and removal of the clot—is only possible if a well trained and thoroughly prepared surgical team is available, and is only practised when the situation is desperate the operative mortality is over 90 per cent (Nygaard, 1938), and spontaneous recovery is the rule rather than the exception The first successful pulmonary embolectomy in Great Britain was reported by Ivor Lewis in 1939

Treatment of pulmonary infarction No specific treatment is required for

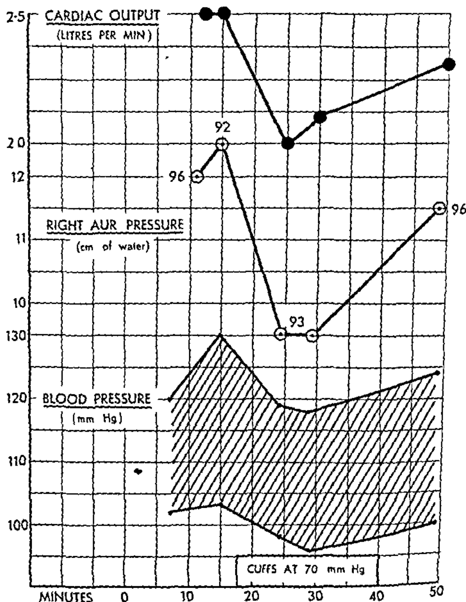


Fig. 16 06—Effect of a venous pressure lowering agent (cuffs on the thighs) on the blood pressure and cardiac output of a case of massive pulmonary embolism

pulmonary infarction itself; but secondary infection or septic embolism calls for sulphonamides or penicillin; morphine may be necessary if there is severe pleural pain; and hæmorrhagic pleural effusion may need aspirating if extensive. Infarction does not contraindicate anticoagulants.

PARADOXICAL EMBOLISM

Valvular patency of the foramen ovale is present in about a third of all individuals, but the opening remains closed because the pressure in the left auricle is higher than that in the right. When the right ventricle fails, however, the auricular pressures may be reversed, the valve then opens and blood is shunted from right to left. This event is improbable in heart failure secondary to mitral stenosis, for the left auricular pressure remains too high. Ideal conditions are presented by acute pulmonary heart failure due to massive pulmonary embolism, for not only is the right auricular pressure then raised, but the left is lowered as in pulmonary stenosis, and emboli are already forthcoming Having passed through the foramen ovale, the embolus is carried into the systemic circulation, and may lodge in any cerebral, visceral, or peripheral artery.

AIR EMBOLISM

Small quantities of air may be injected into the systemic venous system of healthy subjects with little risk; indeed about 15 ml. per kg body weight are required to kill a dog, even when injected rapidly (Wolffe and Robertson, 1935) Fatalities have occurred, however, when air has been accidentally introduced into a vein during an operation, intravenous infusion, therapeutic or diagnostic procedure The clinical features are those of massive pulmonary embolism, but in addition a loud churning sound or millwheel murmur may be heard over the right ventricle and pulmonary artery. Death appears to result from circulatory obstruction due to air-lock in the outflow tract of the right ventricle Treatment consists of turning the patient prone and head-down to bring the outflow tract below the level of the right ventricular cavity (Durant, Long and Oppenheimer, 1947) A similar manœuvre has proved life-saving in dogs, but has not yet been tried in man

FAT EMBOLISM

Globules of fat may penetrate the systemic venous circulation following fractures, usually of the femur, and accidents have occasionally occurred during therapeutic or diagnostic procedures involving the use of oil. Fat embolism has several characteristics which help to distinguish it from other forms First, it happens within a few hours of the accident, perhaps while manipulating the injured limb under anæsthesia, or when moving the patient to the X-ray department. Second, signs of multiple systemic embolism usually complicate the picture owing to the passage of fat globules

through the pulmonary capillaries. Thus, there may be severe headache, drowsiness or loss of consciousness, usually without localising signs; multiple petechial spots may appear in the skin; red cells, albumin, and droplets of oil may be found in the urine. Third, breathlessness and cyanosis are associated with the development of fine crepitations over all areas of the lungs, and skiagrams show an abundance of cotton-wool shadows in all zones. The mortality rate is similar to that of other forms of massive pulmonary embolism, but those who survive recover remarkably quickly – often within forty-eight hours

EMBOLISM DUE TO FOREIGN BODY

Metallic fragments from gun-shot wounds, and even bullets, may enter the circulation in rare instances Such an event should be considered if a skiagram shows an intra-thoracic foreign body when there is no wound of the chest or adjacent structures An intravascular metallic foreign body may remain mobile for several days, and may move against the bloodstream if so directed by the force of gravity Surgical attempts to remove the missile may be foiled by such behaviour. An excellent example was described by Bauer (1943).

MALIGNANT EMBOLI

Cancer cells may infiltrate the systemic venous system and be swept into the lungs in the form of cellular emboli. Subacute pulmonary heart

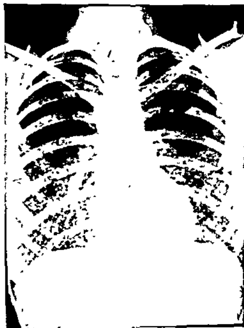


Fig 16 07—Skiagram showing miliary embolic carcinomatosis of the lungs

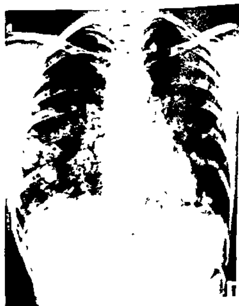


Fig 16 08—Radiological appearances of the lungs showing embolic secondaries due to chorionepithelioma

(By courtesy of Dr. Philip Ellman)

disease develops if more than two-thirds of the vessels are blocked, the clinical features resembling those of massive pulmonary embolism but with an insidious onset and progressive course The diagnosis may be suggested by the skiagram which may show minute miliary lesions (fig 16 07). Cases so far reported have been due either to carcinoma of the stomach (Brill and Robertson, 1937) or breast (Mason, 1940), or to chorion-epithelioma (fig. 16 08).

Subacute cor pulmonale may also be due to multiple pulmonary thromboses secondary to perivascular lymphatic carcinomatous infiltration (Brill and Robertson, 1937)

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CHAPTER XVII

PULMONARY HEART DISEASE

PULMONARY heart disease may be defined as a disorder of the heart resulting from disease of the lungs or of the pulmonary circulation It may be acute, as in massive pulmonary embolism, subacute, as in recurrent thrombo-embolism and secondary carcinomatosis of the lungs, or chronic The acute and subacute forms have already been discussed in the last chapter; the chronic form may be hypertensive or anoxic

HYPERTENSIVE PULMONARY HEART DISEASE

Pathogenesis. Pulmonary hypertension associated with sclerosis of the pulmonary arteries is usually of unknown etiology (primary pulmonary vascular sclerosis or idiopath [illegible] some-
times be due to periarteritis [illegible] *et al*,
1946), recurrent pulmonary [illegible] 6), and
less certainly to other known agents

In idiopathic cases the arterial lesions reported in the literature include atherosclerosis, hypoplasia of the media (Gilmour and Evans, 1946), great thickening of the intima (Barrett and Cole, 1946), and widespread thromboses (Gold, 1946), in others, the pulmonary arterial tree has shown little structural abnormality (East, 1940) Earlier reports reviewed by Brenner (1935) were similar All agree that even when lesions are gross, many vessels escape entirely, and that advanced lesions may be found without hypertrophy of the right ventricle

Various hypotheses have been offered to explain these findings (1) the arterial lesions may be due to idiopathic pulmonary hypertension (East, [illegible]

the arterial lesions described may result from repeated pulmonary embolism (Castleman and Bland, 1946) It is probable that hypertensive pulmonary heart disease may be caused by several different agents, and that the incidence of idiopathic cases will dwindle as more are recognised

It may be noted here that the structure of the small pulmonary arteries and arterioles suggests a passive rather than an active rôle thus there is no muscle in a pulmonary arteriole, merely a layer or two of elastic tissue around the endothelium, in the small arteries (0 1 to 1 0 mm in external diameter) the muscular media averages only 14 per cent of the external diameter of the vessel, compared with 36 per cent in a systemic artery of

the same size (Brenner, 1935) The question therefore arises wheth vessels are capable of sufficient vasoconstriction to embarrass th ventricle. To this may be said that it is unsound to argue about logical events in terms of anatomical structure. Thus capillaries c strict against astonishing pressures, a function retained by pulmonar laries although they have no Rouget cells (Wearn, 1934), and ther valid reason for supposing that small pulmonary arteries and arteri not possessed of considerable contractile power. It is known that t supplied with vasoconstrictor fibres through the sympathetic (B and Dean, 1894), there is evidence that they are supplied with vas fibres also (Daly and Euler, 1932), and they may respond by cons and dilatation to adrenergic and cholinergic drugs respectively (1939) Direct evidence of pulmonary vasoconstriction in man ha obtained recently by Motley and Cournand (1947) who demonst considerable rise in pulmonary arterial pressure during periods of a anoxia

Incidence The disease may occur in either sex and at any age, in childhood, but is rare; out of 100 cases of chronic pulmonary heart analysed by the author, only three could be classified as idiopathic.

Physiology Pulmonary hypertension of any etiology imposes a me cal burden on the right ventricle and pulmonary artery, *just as sy* hypertension affects the left ventricle and aorta, the right ventricle trophies and the pulmonary artery dilates

Sooner or later pure right ventricular failure develops the cardiac is low and cyanosis is peripheral. The arterial oxygen saturation re normal until near the end, but may then fall to about 80 per cent.

Clinical features. Idiopathic cases are rarely recognised until f vanced, but evidence is accumulating which suggests the likelihoo much longer course than generally believed.

The findings are usually those of pure right ventricular failure normal rhythm, although auricular flutter or fibrillation may develop The jugular venous pressure is raised, and the "a" wave conspi there may well be functional tricuspid incompetence, the liver is en and tender, and there is usually dependent œdema; but the lungs ar and there is no orthopnœa. Cyanosis is often conspicuous, but is asso with cold extremities, a low cardiac output, a normal or near normal a oxygen saturation, and a high arterio-venous oxygen difference; it is fore peripheral, not central. Polycythæmia and clubbing are usually a

The cardiac impulse is diffuse and right ventricular in quality; ther be *systolic lifting in the third left intercostal space over the right* ventr outflow tract. There is no loss of cardiac dullness, rather the revers there are no other signs of emphysema. There are usually no mu *unless* functional pulmonary incompetence develops; but the pulm element of a normally split second heart sound is loud and high pit and presystolic gallop may be heard to the left of the sternum

The electrocardiogram shows a pulmonary P wave and strong right ventricular preponderance (fig. 17 01)

Fluoroscopy reveals a prominent pulmonary artery and right ventricle, and though the proximal pulmonary vascular shadows may be heavy, the more peripheral lung fields are clear (fig. 17.02). Hilar pulsation may be seen, but is unimpressive. The right auricle is moderately dilated, the left





Fig 17 02—Skiagram showing prominence of the pulmonary arc and right ventricular enlargement in a case of idiopathic pulmonary hypertension

Fig 17 01 (*left*)—Electrocardiogram showing prominent P waves and right ventricular dominance in a case of idiopathic pulmonary hypertension

flat, and there are no signs of emphysema Catheterisation reveals an extremely high pressure in the right ventricle and pulmonary artery (the mean pulmonary artery pressure ranged between 55 and 81 mm Hg in five cases of the author's), and no shunt

Diagnosis The features described make a characteristic and pathognomonic picture Pure pulmonary stenosis is excluded by the quality of the second sound and by the absence of a basal thrill, atrial septal defect by lack of pulmonary plethora, character of the second heart sound, inconspicuous hilar pulsation, and electrocardiogram, anoxic pulmonary heart disease by the lack of emphysema, obviously low cardiac output, and peripheral rather than central cyanosis, mitral stenosis by the absence of a mitral diastolic murmur, and by the flat left auricle and different P wave

Diagnostic difficulty may arise, however, when pulmonary hypertension causes reversed interatrial shunt through a patent foramen oval as discussed on page 245.

Prognosis The disease is always progressive and is usually fatal within two years of its recognition.

Treatment. The results of treatment are poor. a low sodium diet, mersalyl, digitalis, venesection and thiouracil may prolong life, but the patient usually remains bed-ridden and symptoms become increasingly difficult to control; an oxygen tent does not help.

ANOXIC PULMONARY HEART DISEASE

Definition The anoxic type of pulmonary heart disease invariably results from emphysema, and depends upon the combination in varying degree of pulmonary hypertension and hypoxia, with the emphasis on the latter.

Pathogenesis. The essential underlying pathology is emphysema, however caused. The great majority of cases are due to chronic bronchitis or bronchial asthma, relatively few to bronchiectasis, silicosis, other forms of pneumoconiosis (Griggs, Coggin and Evans, 1939), pulmonary tuberculosis, congenital cystic lung, or kyphoscoliosis (Chapman, Dill and Graybiel, 1939)

When the vital capacity becomes seriously reduced, ventilation may become inadequate, even at rest, the arterial oxygen saturation falls (McMichael and Sharpey-Schafer, 1944) and the carbon dioxide content of the arterial blood rises (Taquini, Fasciolo, Suarez and Chiodi, 1947). Cyanosis is thus central in origin and breathlessness may be chemical rather than reflex *The deficiency in gaseous exchange* tends to be compensated by an increase in cardiac output (McMichael and Sharpey-Schafer, 1944) rather than by polycythæmia, but there is also an increase in utilisation of available oxygen. At the same time the pulmonary arterial pressure rises (Bloomfield *et al.*, 1946), probably reflexly as a result of pulmonary hypoxia (Motley, Cournand *et al*, 1947). Secondary structural changes in the pulmonary arteries, such as atheroma and intimal thickening, develop sooner or later in most cases, and may increase the hypertension

Incidence Anoxic pulmonary heart disease is much more common than statistical evidence at present indicates; this is partly due to the casual attitude often adopted towards cases of chronic bronchitis and emphysema, and partly to the fact that such cases are not usually sent to cardiovascular clinics; the diagnosis is not easily made without special investigation, unless there is heart failure, and bronchopneumonia may obscure the cardiac factor terminally

The condition probably accounts for 5 to 10 per cent of all cases of organic heart disease. It is at least five times more common in men than in women, and about 75 per cent of the patients are over 50 years old (Spain and Handler, 1946).

Clinical features. The patient is usually a man, neither very old nor very

young. He commonly gives a history of bronchial asthma or of recurrent winter bronchitis for many years, with increasing breathlessness over the last year or two, and may have sought advice because of recent swelling of the legs. Cross-examination yields little further information he may have had attacks of tightness in the chest associated with breathlessness, but not paroxysmal cardiac dyspnœa, he may have had substernal discomfort, but not true angina; he may prefer to be propped up a little at night, but usually raises no objection to lying flat

Physical signs Emphysema is usually obvious: the chest is distended and moves little with respiration; cardiac dullness is absent and the percussion note is generally tympanitic; the breath sounds are faint Central cyanosis may be gross, as in the case discussed by Ayerza, or scarcely detectable It may be recognised in warm situations, as in the conjunctivæ and inner sides of the lips, where it is unlikely to be confused with peripheral cyanosis Polycythæmia and clubbing are rare. The hands are warm, capillary pulsation, digital throbbing, a modified water-hammer pulse and increased pulse pressure may often be demonstrated. Elevation of the jugular venous pressure and tachycardia may confirm the impression that the cardiac output is raised. Papilloedema sometimes occurs (frontispiece)

The heart itself is apt to be camouflaged by over-expanded lung the apex-beat is impalpable, the left cardiac border impossible to locate by percussion, the heart sounds difficult to hear, and the second sound at the base often inaudible; there are no murmurs, but right-sided presystolic gallop may be heard or felt just to the left of the sternum in the fourth intercostal space.

When there is true congestive failure the liver is distended and tender, and dependent œdema is the rule.

In severe cases vasomotor collapse is apt to occur when some superimposed broncho-pulmonary infection lowers the arterial oxygen saturation relatively suddenly. the blood pressure drops, the pulse becomes small and thready, the cardiac output low and the skin cold and clammy, the outlook is then very grave.

The electrocardiogram Emphysema alone does not materially affect the electrocardiogram, although it may cause clockwise rotation about the antero-posterior and longitudinal axes (viewed from the front and below) Thus there may be right axis deviation in standard leads, an RS pattern in lead VL, a QR pattern in lead VF, and an RS pattern from V1 as far as V5 or even V6 (fig 17.03) When the heart is exceptionally vertical, VR and VL may be indistinguishable, or backward tilting of the apex may cause VL to resemble an œsophageal lead from the back of the heart

In 100 cases of chronic pulmonary heart disease analysed by the author (Wood, 1947), the following electrocardiographic appearances were found in *standard leads* (fig 17.04a to e).

Pulmonary P wave (fig 17 04) . . .	85
Right axis deviation—	
with T2 (and often T3) inverted (fig 17.04a)	[illegible]

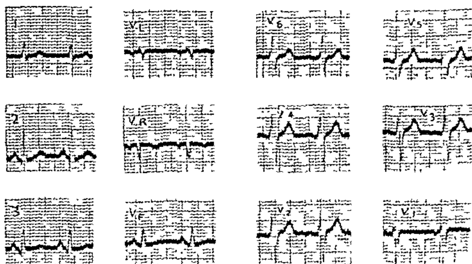


Fig 17 03—Electrocardiogram in a case of emphysema showing a vertical electrical position and clockwise rotation (viewed from below)

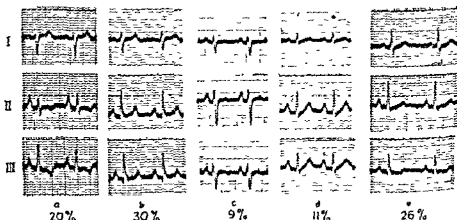


Fig 17 04—Standard lead electrocardiographic findings in 100 cases of anoxic pulmonary heart disease

(a) Right axis deviation with inversion of T3 (and often T2)

(b) Right axis deviation with upright T waves

(c) Dominant S wave in all standard leads

(d) Tendency to right axis deviation

(e) Normal QRS axis.

The pulmonary P wave is seen in all

Prominent S wave in all leads (fig. 17.04c) . 9
Tendency to right axis deviation (fig. 17.04d) . 11
Normal axis of QRS (fig. 17.04e) . 26
Right bundle branch block 4
Low voltage 40

Multiple chest leads revealed the following:

Normal QRS deflections in the majority (fig 17 05a and b)

Per cent

Inversion of T from V1–V3 (fig 17 05c) . . 13
Dominant R wave in V1 with conspicuous S in V5 (fig. 17 05d) 16
Dominant S wave from V1–V5 (fig 17 05e) . 16

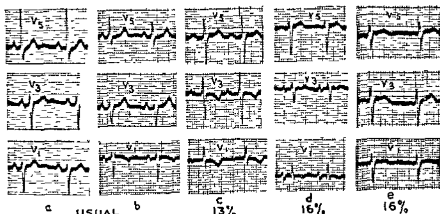


Fig [illegible]

Unipolar limb leads nearly always showed a vertical electrical position

Particular attention is drawn to the frequency and importance of the pulmonary P wave (fig 17 06 and 17 07) In normal controls the maximum auricular deflection very rarely measures more than 1 5 mm in amplitude and averages 1 mm (fig 17 08) The pulmonary P wave commonly ranges between 2 and 3 mm in height, but is never widened It is not seen in normal vertical hearts, which refutes the suggestion that it depends on cardiac rotation due to emphysema It cannot be attributed to anoxia, for it is an early finding and tends to diminish in voltage when anoxia becomes severe, nor is it present in cases of severe anæmia It cannot be ascribed to an elevated cardiac output, for it is seen in a much less conspicuous form in cases of thyrotoxicosis in which the cardiac output is considerably higher, moreover, as already mentioned, P is of low voltage in severe

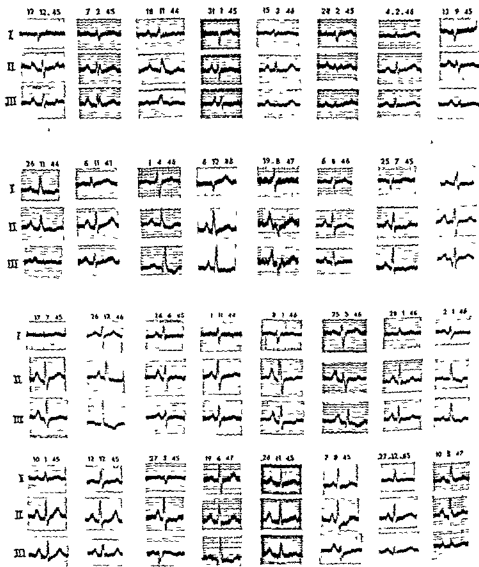


Fig 17 06—Standard limb lead electrocardiograms of 32 unselected cases of anoxic pulmonary heart disease with relatively low voltage showing the frequency, amplitude, and shape of the pulmonary wave

chronic anæmia with outputs up to 14 litres per minute Intracardiac pressure studies have revealed little correlation between this P wave and the right auricular pressure, but there appears to be some association be-

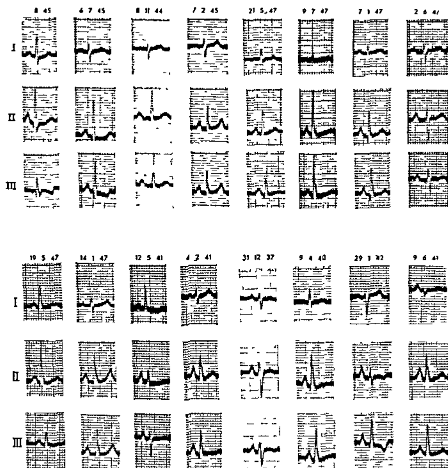


Fig 17 07—Standard limb lead electrocardiograms of a further 16 unselected cases of anoxic pulmonary heart disease with normal voltage showing the frequency, amplitude, and shape of the pulmonary P wave

tween it and the right ventricular pressure Just on what such a relationship may depend is unknown

The pulmonary P wave is probably the earliest sign of cardiovascular disturbance resulting from emphysema, or at least competes in this respect with elevation of the right ventricular pressure and slight reduction of the arterial oxygen saturation, it may develop several years before the onset of heart failure

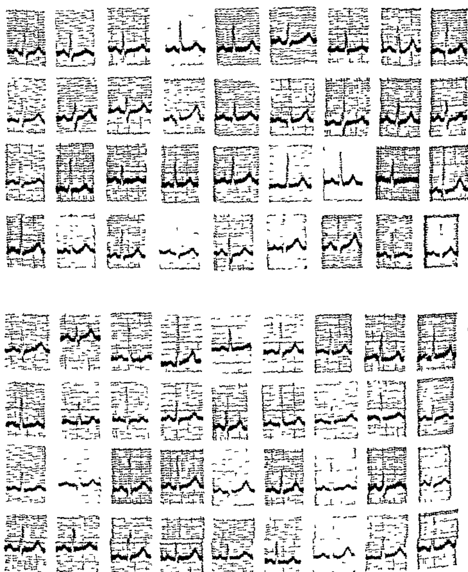


Fig 17 08—The maximum P waves in one or other of the standard leads (usually lead 2) of 72 unselected normal controls are shown for comparison with Figs 17 06 and 17 07.



(a)



(b)

Fig 17 09 (a), (b)—Skiagrams of two advanced cases of anoxic pulmonary heart disease showing dilatation of the pulmonary arc and of the left and right branches



(a)



(b)

Fig 17 10 (a)—Right anterior oblique position showing the increased density and diameter of the pulmonary artery at its bifurcation
(b) Left anterior oblique position showing the left pulmonary artery forming an arc almost as dense and as large as the aortic arch

Fluoroscopy. Prominence of the main branches of the pulmonary artery at the hila, with or without dilatation of the main pulmonary arc, is seen in over 50 per cent of cases of severe emphysema (Parkinson and Hoyle,

Pulsation of the pulmonary artery and its main branches may be seen sometimes, but does not compare with that in atrial septal defect, and as a rule is absent. Peripheral vascular markings are relatively unimpressive. Enlargement of the right auricle is rare in the absence of failure. The left auricle is flat, and a prominence on the left border of the heart between the pulmonary and left ventricular arcs is never seen. Owing to the raised cardiac output and to the frequency of coincident essential hypertension, the aortic knuckle is usually well seen, and may be unduly prominent.

Finally, there may be evidence of emphysema: widening of the rib spaces, elevation of the ribs and clavicle, depression of the diaphragm, and increased translucency of the lung parenchyma. However, emphysema is not cor pulmonale, and too much should not be deduced from its presence.

Special investigations. The vital capacity is greatly reduced, and is usually below 1500 ml. The residual air is increased proportionately, the total lung volume remaining normal. Central cyanosis may be proved by arterial puncture the arterial oxygen saturation is usually between 60 and 80 per cent, but may be much lower

The pulmonary artery and right ventricular pressures may be measured by means of cardiac catheterisation and are usually moderately raised, but less so than in primary pulmonary hypertension.

In 19 cases of emphysema without right ventricular failure, Cournand and his colleagues found the systolic right ventricular pressure was normal (18 to 30 mm Hg) in 5 and between 34 5 and 57.5 mm Hg in 14 (Bloomfield *et al.*, 1946) They regard this rise as the earliest evidence of pulmonary heart disease

Cardiac outputs commonly range between 5 and 9 litres per minute (McMichael and Sharpey-Schafer, 1944), and do not seem to reach the high levels encountered in anæmia, thyrotoxicosis, and large arterio-venous shunts

The right auricular pressure tends to be raised when the cardiac output is increased, and may be high in clinical congestive failure On the other hand, in some cases of emphysema it is remarkably low, the mean pressure being less than minus 10 cm. of saline below the sternal angle; this may be attributed to anterior displacement of the sternal angle and to an unusually low intrathoracic pressure.

Diagnosis. The usual clinical problem is to decide whether the cardiovascular system is involved in a known case of emphysema; but difficulty may also arise in distinguishing pulmonary heart disease from other cardiopathies, and especially in unravelling a mixed etiology. Other hyperkinetic

circulatory states may have to be excluded, particularly beri-beri in alcoholics, but also thyrotoxicosis, secondary carcinomatosis of the liver, and Paget's disease of bone in emphysematous subjects The commonest mixed [illegible]

In the stage of low blood pressure and reduced cardiac output, clinical diagnosis may be even more difficult Toxic vasomotor collapse from bronchopneumonia may cause confusion; mitral stenosis, Pick's disease, atrial septal defect, mediastinal tumour, massive pulmonary embolism, and many other conditions may have to be considered. The correct diagnosis can usually be made after full investigation, but the first clinical impression can be very misleading

Prognosis. The diagnosis of chronic anoxic pulmonary heart disease usually carries with it a grave prognosis, few cases surviving a year, but such diagnoses are rarely made before the onset of failure With the newer methods of investigation, circulatory involvement should be recognised much earlier, perhaps by 5 or 10 years, and appropriate treatment might then prolong life.

Treatment Vigorous preventive and symptomatic treatment of bronchitis and asthma may delay the development of serious emphysema indefinitely Half-hearted measures must be condemned when the ultimate fate of these patients is realised

By the time the cardiovascular system is involved, emphysema is usually far advanced A partly reversible state may be encountered however, when acute bronchitis, bronchopneumonia, or an asthmatic bout is superimposed on chronic changes of only moderate degree In such cases, infection should be treated promptly with penicillin or other forms of chemotherapy, and bronchial spasm relieved by a dust-free atmosphere and antispasmodics

Although details of such treatment cannot be considered in a work of this kind, one or two observations are necessary Morphine is frequently lethal owing to its depressing effect on respiration, pethidine may quieten a restless patient just as well, is a good antispasmodic, and does not depress respiration Subcutaneous adrenaline is still the most effective way of relieving bronchial spasm, newer remedies, such as the antihistamine drugs, may be given in addition but not as a substitute Isopropyl-*nor*-adrenaline, which may be administered in sublingual tablets in doses of 20 to 40 mg , is a useful preparation Antispasmodics that improve the cardiac output or coronary circulation, such as aminophylline may be chosen in preference to those that do not

Whether the case is complicated by infection and bronchial spasm or not, it is vitally important that the patient should be nursed in an oxygen tent The effect of improving the arterial oxygen saturation is often dramatic it prevents fatal vasomotor collapse, reduces the work of the heart and may lower the pulmonary blood pressure

Mersalyl, a low sodium diet, and venesection should be used with caution. Howarth, McMichael and Sharpey-Schafer (1947) have shown that in most cases with raised cardiac outputs the venous pressure is already at an optimum level, and that lowering it by any means may reduce the output and harm the patient. In a minority, however, the heart is overloaded and then responds to such treatment in the usual way. Although clinically it may not be easy to judge the physiological state of the circulation, warm extremities and a full bounding pulse contraindicate all venous pressure lowering agents, whereas cold extremities, a small pulse and low blood pressure demand them (when the venous pressure is raised) When œdema is gross and the jugular venous pressure over 7 cm. saline above the sternal angle, mersalyl and a low sodium diet should probably be tried. Venesection is best avoided in all cases, as it is too drastic and may prove fatal if ill judged Digitalis or strophanthin may be used without fear when the usual clinical indications are present.

If, after relief of bronchial spasm and infection, the vital capacity remains critically low, and the arterial oxygen is below 80 per cent when the patient is out of the tent, thiouracil should be seriously considered as a means of reducing the oxygen requirement (page 385).

OTHER FORMS OF PULMONARY HEART DISEASE

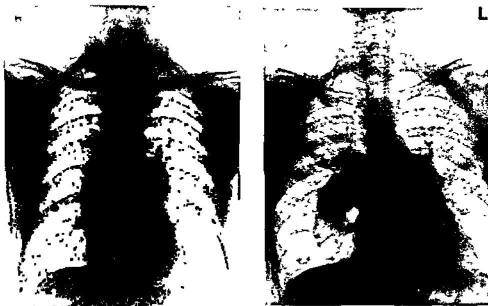
Ayerza's disease Much confusion has arisen from the use of this term. It has been applied to cases of intense cyanosis and polycythæmia associated with syphilitic or other disease of the pulmonary arteries (Boyd, 1931). The facts are that Ayerza, of Buenos Aires, in an unpublished clinical lecture (1901) described a single case of heart failure in which the patient was so cyanosed as to be almost black—a cardiac negro. Autopsy revealed much enlargement of the right side of the heart, dilatation of the bronchi, and peribronchitis Neither syphilis nor the state of the pulmonary vessels was mentioned Arrillaga (1913, 1924) was, perhaps, chiefly responsible for stressing the syphilitic origin of such cases, although other authors from the Argentine believed the arterial lesions to be atherosclerotic. Brenner (1935), after reviewing the evidence, concluded that there was no good reason for retaining the term Ayerza's disease, on the grounds that published cases described nothing but chronic cor pulmonale

Pulmonary heart disease associated with deformities of the chest. Gross kyphoscoliosis accounts for perhaps 5 per cent of cases of chronic cor pulmonale The condition is associated with extensive collapse-atrophy of part of the lung and severe emphysema of the remainder. Cardiovascular involvement is similar in type to that associated with other forms of pulmonary disease complicated by emphysema; kinking of the aorta (Corvisart) plays no part in its development.

The average age of death in these cases is about 30 years A curious form of syncope has been described in a number (Chapman, Dill and Graybiel,

1939), possibly due to sudden lowering of the right auricular pressure consequent upon compression of the inferior vena cava in certain postures (page 196).

Aneurysm of the pulmonary artery. Aneurysm of the pulmonary artery is rare, being found in less than .01 per cent of all autopsies, and accounting for less than 0.5 per cent of all aneurysms (Deterling and Clagett, 1947) The sexes are represented equally, and about one-third of the patients are



(a) 22nd March 1944 (b) 5th December 1946

Fig 17 11—Development of aneurysmal dilatation of the right pulmonary artery in a case of anoxic cor pulmonale

under 30 years of age (Boyd and McGarack, 1939) The etiology is believed to be a congenital defect in the wall of the pulmonary artery in about 40 per cent, syphilis in 30 per cent and chronic cor pulmonale with atherosclerotic pulmonary arteries in 30 per cent The diagnosis may be obvious

ably quickly (fig 17 11), underlying congenital weakness of the arterial wall is difficult to exclude Thrombosis may occur in the sac, or the whole vessel may be occluded, but apart from such a complication the aneurysm is unlikely to influence the course of the primary disease Rupture is very rare

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CHAPTER XVIII

THYROTOXICOSIS AND THE HEART IN MYXŒDEMA

THYROTOXIC HEART DISEASE

THE cardiovascular system is clearly involved from the onset of thyrotoxicosis, although the term thyrotoxic heart disease is usually reserved for the late stage when auricular fibrillation or congestive heart failure dominates the scene Such a distinction is artificial and simply means that a young and healthy heart can maintain a high output for years without distress, but that an aged heart cannot

Historical note Thyrotoxic heart disease was first adequately described by Caleb Hillier Parry (1815, 1825) of Bath, who witnessed his first case in 1786 Flajani's publication of the details of one case (1802) appeared first, but cannot be compared with Parry's account Graves' description (1835) is also inferior Carl von Basedow (1840), a general practitioner at Merseburg, Germany, called special attention to exophthalmos and drew a vivid picture of most of the features of primary exophthalmic goitre as we see it today, omitting only tremor, which was later recognised and added to the Merseburg triad (exophthalmos, goitre and palpitations) by Pierre Marie (1883) For further historical details the reader is referred to the classical monographs of Cecil Joll (1932) and of Means and Richardson (1938).

NATURE OF THYROID HORMONE

The exact composition of thyroid hormone is not yet known. In 1895, Baumann obtained from thyroid tissue a protein-free, physiologically active substance containing 10 per cent of iodine, which he called iodothyrin In 1899, Oswald showed that the active principle stored in the gland was attached to a protein in the form of thyroglobulin: this is the chief constituent of colloid Kendall isolated thyroxine in 1915, showed that it contained 65 per cent of iodine, and demonstrated its potency. These researches culminated in the synthesis of thyroxine by Harington and Barger in 1927

Thyroxine, however, accounts for only 40 to 50 per cent of the total iodine in the thyroid gland, is relatively insoluble, and is not believed to be identical with thyroid hormone. The rest of the thyroid iodine is found in the practically inert substance, di-iodotyrosine, a likely precursor of thyroxine. According to Harington (1933), thyroxine and di-iodotyrosine are probably linked with amino-acids as constituents of thyroglobulin in colloid, and the natural thyroid hormone is perhaps a thyroxine—containing peptide.

PATHOLOGY OF GOITRE

The normal thyroid gland consists essentially of numerous acini lined with epithelium and containing colloid material rich in iodine, from which thyroid hormone appears to be liberated according to the demand. When the gland is stimulated, the epithelium assumes an active columnar form, and colloid tends to disappear. When there is little or none left, the walls of the acini may become crenated, like any other vesicle whose contents have been removed In this phase the gland as a whole is soft and vascular, and is not enlarged. When the stimulus ceases, involution takes place· the epithelum flattens, colloid reappears, and the acini become distended This is the resting phase, and is characterised by a firmer, less vascular gland of somewhat larger size. If the stimulus to activity is excessive the morphological changes described above are supplemented by true hyperplasia of the acinar epithelium, and subsequent involution may be incomplete, leading to permanent enlargement of the gland

Simple goitre is due to benign hyperplasia, and develops when iodine supplies are short or diverted, especially when thyroid demands are heavy (Marine, 1927) This response to iodine lack is believed by some to be mediated by the production of excessive amounts of thyrotropic hormone from the anterior pituitary. Endemic goitre due to lack of iodine in the soil occurs in New Zealand, parts of Italy and North America, and in many other mountainous districts or places remote from the sea Iodine diversion may be due to polluted water (Marine and Lenhart, 1910, McCarrison, 1927) Increased demands for thyroid hormone occur at puberty and during pregnancy

Colloid goitre represents the resting involuted phase of previous benign hyperplasia (Marine, 1930) When the stimulus subsides, colloid reaccumulates in the acini, intervening walls between distended crowded vesicles break down to form cysts, and the whole gland becomes tense and big This process is innocent and causes no symptoms except possible discomfort in the neck

In primary Graves' disease persistent uncontrolled stimulation of the thyroid gland of unknown cause leads to marked hyperplasia and to wild manufacture and liberation of excessive amounts of thyroid hormone The acinar epithelium is columnar and proliferated, the walls of the acini markedly crenated, and the colloid practically all gone The gland as a whole is soft, vascular and enlarged

Nodular goitre is usually regarded as the end-result of repeated cycles of hyperplasia and incomplete involution The process probably begins with failure of complete involution of a previously stimulated and hyperplastic gland Subsequent stimulation leads to local hyperplasia of these hypo-involuted nests, and subsequent involution to local nodules of colloid goitre Such a process may be repeated indefinitely Thyrotoxicosis from nodular goitre depends chiefly upon the activity of the hyperplastic nests, the nodules themselves being mostly inert The term adenomatous goitre

is therefore incorrect when applied to this type of lesion, and should be reserved to describe those cases in which thyroid nodules (usually single) are composed of solid masses of cells of fœtal type. Compared with primary Graves' disease, nodular goitre usually runs a longer and less dramatic course, which by its very nature is necessarily phasic, periods of activity alternating with periods of relative quiescence. Why production of thyroid hormone should exceed the demand is no more understood than it is in primary Graves' disease The implication of the anterior pituitary thyrotropic hormone may explain part of the mechanism, but in no way solves the problem.

Physiology of the circulation under the influence of thyroxin. The administration of thyroxin to man and mammals is followed, after a time-lag of several days, by an appreciable rise in the basal metabolic rate. The increased oxygen requirement is met by elevation of the cardiac output, not by greater utilisation of available oxygen (as occurs when the B.M.R is raised by dinitrocresol), nor by polycythæmia The high minute-output is maintained more by tachycardia than by a raised venous pressure, the stroke-volume being but little increased (Friedberg and Sohval, 1937) The strength of cardiac contraction is probably enhanced These effects are usually attributed to the direct action of thyroxine on the heart

At the same time the peripheral blood flow is greatly increased, there is obvious vasodilatation in the skin, and adrenergic responses are magnified

Morbid anatomy of the thyrotoxic heart. There are no macroscopic changes in the thyrotoxic heart prior to the onset of auricular fibrillation and failure, until then the heart-weight remains normal Cases exhibiting cardiac embarrassment during life may still show little at necropsy except some increase in heart-weight and evidence of congestive failure (Kepler and Barnes, 1932) In a few, however, there are scattered foci of fibrosis (Rake and McEachearn, 1932)

CLINICAL FEATURES

The hyperkinetic circulation of primary Graves' disease is usually well tolerated because the subjects are young; but in middle-aged or elderly people with toxic nodular goitre cardiac embarrassment is the rule The sex-ratio favours women in the proportion of about 6 : 1 (Fraser and Dunhill, 1934). A family history of goitre is found in 45 per cent of cases (Bruun, 1945). Contributory factors include pregnancy, the climacteric, infection (such as tonsillitis) and perhaps emotional shock, although the scarcity of thyrotoxicosis amongst active service casualties in the first two world wars was noteworthy. The rôle of iodine has already been discussed

Of the symptoms, loss of weight, heatintolerance, agitation or restlessness, palpitations and fatigue are the most important. Loss of weight associated with a voracious appetite is particularly suggestive. Palpitations

t or to paroxysmal

Whilst the symptoms themselves are important, the manner in which they are told and the general behaviour and appearance of the patient are often more so The subject is usually a woman; she is commonly thin and talks quickly, often gesticulating to lend emphasis to her remarks She may wear a scarf to hide an unsightly swelling in her neck, but her clothing is otherwise light. One of Parry's patients liked to sit in a draught, stripped to the waist, in order to keep cool (Parry, 1815). A good moment to look for the goitre is towards the beginning of the interview, when the patient may lean forward in her chair, and swallow once or twice in nervousness The eyes are characteristic, not so much because of exophthalmos, which is usually absent, but because of their typical stare. The trend of the patient's conversation is often illuminating, and in sharp contrast to that of the anxiety neurotic. The latter complains of symptom after symptom in a challenging fashion, exaggerating their severity, and stressing his inability to cope with them The thyrotoxic patient tries to explain away her symptoms: she feels the heat, but of course it has been very warm recently, she is losing weight, but she supposes she was too fat before, she gets tired and irritable, but she knows she tries to do too much; and so on

Physical examination may reveal a wealth of signs which are all directly or indirectly attributable to excess of thyroid hormone, except exophthalmos and goitre. They may be suitably described under four main headings.

1. *The eyes.* Exophthalmos may be present (fig 18 01), but is uncommon in toxic nodular goitre. It is occasionally unilateral (fig 18 02) Artificial glass eyes may also become proptosed Its mechanism is still a subject of controversy (Zondek and Ticho, 1945), but exophthalmos is certainly not due to sympathetic stimulation, for it is not relieved by sympathectomy (Shaw, 1929), nor is it due to excess of thyroid hormone, which never reproduces it Moreover, exophthalmos occasionally becomes more marked after thyroidectomy or treatment with thiouracil In severe cases of exophthalmic ophthalmoplegia and malignant exophthalmos, thyrotoxicosis may be minimal, and the protrusion of the eye-ball appears to be secondary to intense œdema of the orbital contents (Brain and Turnbull, 1938) Of great interest is the exophthalmos that can be produced in guinea-pigs (also in rabbits and fish, but not so far in man) by injecting thyrotropic hormone, especially if the thyroid gland is first removed (Marine and Rosen, 1933) All these facts point to the likelihood of the pituitary being directly responsible, and provide further evidence that thyrotoxicosis may depend upon a primary pituitary disorder

Retraction of the upper lid (fig 18 03), revealing the white sclerotic above the iris (Dalrymple's sign), which may be unilateral, is also uncommon in toxic nodular goitre It should be distinguished from exophthalmos, which reveals the white sclerotic below the iris by mechanically displacing the lower lid (Pochin, 1937–8)

If the patient looks up, and then lowers the eyes to watch a descending object, the upper lid lags behind the movement of the eye-ball, revealing



(a)

Fig 18·01—Exophthalmic goitre. The first photograph (a) (in gipsy dress) was taken in 1933, the second (b) in 1936 The white sclerotics are seen below the iris due to mechanical displacement of the lower lid



(b)



Fig 18 02—Unilateral lid retraction and exophthalmos



Fig 18 03—Lid retraction and characteristic thyrotoxic stare.

the white sclerotic above the iris (von Graefe, 1864) Lid-lag and lid-retraction were for a long time attributed to stimulation of the sympathetic reinforcement of the levator palpabræ superioris (von Graefe, 1864), but if sympathetic stimulation were responsible, the lower lid would also be retracted, which it is not (Pochin, 1937–8, 1939). Moreover, both exophthalmos and lid-retraction may occur when the ocular sympathetic is paralysed (Brain, 1939). In the light of these findings von Graefe's hypothesis is untenable

The characteristic stare has already been mentioned It is more than lid retraction and infrequent blinking (Stellwag's sign), it is a look which may occur independently and which can be recognised with experience The other eye-signs of the textbooks are less important failure to wrinkle the forehead when the eyes are cast up (Joffroy's sign) may depend upon lid-retraction and exophthalmos; divergent strabismus as the eyes focus on an approaching object (Moebius' sign) may be due to weakness of the oculomotor muscles as a result of stretching.

2 *The hands* The hands are warm, pink, and slightly moist on both surfaces; they are restless and expressive, and may show a fine, even, constant tremor In contrast, the hands of a psychoneurotic are cold and clammy, being wet on the palms but not at the back, they tend to be inert and expressionless, tremor is coarse, irregular and inconstant



Fig 18 04—Substernal goitre revealed by X-rays

3. *The goitre.* If a goitre is not seen, it may be discovered by palpation It is best to stand behind the patient, and to place the thumbs behind the sternomastoids, and the fingers in front On asking the patient to swallow, a nodular swelling may be felt moving upwards Posterior enlargement may be detected readily with this technique Practically all cases of thyrotoxicosis have a goitre, although it is sometimes difficult to demonstrate (so-called masked hyperthyroidism) In such instances, it may become more convincing after a course of Lugol's iodine Occasionally it is substernal and may be revealed by fluoroscopy (fig 18 04)

The goitre of thyrotoxic heart disease is commonly nodular, irregular and asymmetrical It may displace the trachea to one side, and the common carotid artery to the other, and on rare occasions it may compress the trachea, causing cough, dyspnœa, and stridor Sudden enlargement is usually due to hæmorrhage within a nodule or cyst Degenerated nodules may become calcified

Primary exophthalmic goitres are uniformly enlarged, smooth, and fleshy

They are similar to simple hyperplastic goitres, but more vascular. Sometimes an arteriovenous continuous thrill and murmur may be detected over the gland Colloid goitres are also smooth and symmetrical; but they are harder and, as a rule, larger. After a course of iodine, primary exophthalmic goitre may feel like colloid goitre. Nodular goitre should be distinguished from other causes of thyroid enlargement and from other swellings in the neck

Fœtal adenoma (Wolfler, 1883), whether regarded as a true neoplasm arising in nests of embryonic epithelial cells, or as an ordinary hyperplastic nodule in which the vesicles are unusually small and devoid of colloid (Joll, 1932), presents clinically as a firm smooth single tumour within the substance of the thyroid gland It is usually innocent.

What were believed to have been *malignant changes* were found by Wilson (1921) and by Speese and Brown (1921) in about 5 per cent of all goitres that were surgically removed, but their histological criteria have been disputed and the true incidence of malignancy is probably lower. In non-toxic goitres it may be between 1 and 4 per cent (Lerman, 1944), but in toxic nodular goitre it is extremely rare Thus Means (1937) said he had not seen a single case, and Crile (1936) met no instance of toxicity amongst 249 malignant cases Malignancy should be suspected when a goitre grows rapidly, becomes unduly hard, causes dysphagia, involves the recurrent laryngeal nerve, surrounds and buries the common carotid artery, obstructs the internal jugular vein, causes pain by involving adjacent sensory nerves, or when fixation can be demonstrated. Enlargement of neighbouring cervical lymph glands is particularly suggestive Metastases are found especially in the lungs and in bone

Riedel's disease (Riedel, 1896) may be readily confused with malignant disease clinically It is characterised by a brawny induration of part or all of the thyroid gland, sometimes involving surrounding tissues. It is a slow fibrotic process of unknown etiology, affecting individuals of either sex and of any age Pain, dyspnœa, dysphagia, huskiness of the voice and obstruction of neighbouring vessels occur, and the gland is soon fixed; but lymph nodes are not enlarged and thyrotoxic symptoms are unusual

Lymphadenoid goitre (Hashimoto's disease) is seen particularly in women over the age of 45 The whole gland is involved from the start, surrounding structures are not affected, and myxœdema usually develops (Joll, 1932) Microscopically, acinar remnants are scattered among masses of lymphoid tissue.

Acute thyroiditis may complicate a variety of infections, but is rare It may be suppurative or non-suppurative according to the nature of the invading organism and to the severity of the attack. Clinically it is characterised by a painful, tender, uniform swelling of the gland accompanied by fever. Cellulitis with or without suppuration may invade surrounding tissues. Thyrotoxic symptoms may be associated, but usually subside with the inflammation

Thyroglossal cyst is essentially a mid-line structure, developing from remnants of the thyroglossal duct, and moves upwards when the tongue is protruded. It is of cosmetic rather than medical significance

4. *Cardiovascular signs.* Vasodilatation in the skin and muscle is nearly always present, and may be recognised by hot extremities, throbbing digital vessels, capillary pulsation, modified water-hammer pulse, and raised pulse pressure. Tachycardia is the rule, and persists during sleep (Boas, 1932) The action of the heart is vigorous, the cardiac impulse being forceful and displaced a little to the left, and the heart sounds slapping. A systolic murmur may be heard at apex or base, and a thrill may be felt on compressing the carotid or subclavian artery Rarely, a functional mitral diastolic murmur may be heard.

Auricular fibrillation may be initiated by overdosage of thyroxine in patients with normal hearts. It occurs in 10 per cent of all cases of thyrotoxicosis, and in 84 to 96 per cent of those with cardiac failure, and may be paroxysmal or persistent It is rare in young subjects, but becomes progressively frequent with advancing years During attacks the ventricular rate is apt to be very fast, and the patient may complain of violent palpitations



Fig 18 05—Skiagram showing slight prominence of the aortic knuckle and of the left pulmonary arc in a case of thyrotoxicosis

Cardiac enlargement and failure are also relatively late developments, and are unusual with normal rhythm, but often follow the onset of auricular fibrillation Congestion is systemic rather than pulmonary An appreciable proportion of such cases (over 50 per cent according to Magee and Smith, 1935) are complicated by hypertension or other forms of heart disease.

X-rays may show slight prominence of both the aortic knuckle and left pulmonary arc (Parkinson and Cooke

QRS may be augmented (fig. 18 06).

5 *Other and less constant features* Neurological signs are rare, they include exophthalmic ophthalmoplegia and myasthenia—sometimes resembling myasthenia gravis, but not responding to prostigmine Curious

patches of local myxœdema occasionally occur on the legs, koilonychia has been described, and the skin may be unduly pigmented.

Decalcification of bone is not uncommon; a negative calcium and nitrogen balance may be demonstrated, the blood cholesterol may be rather low, sugar tolerance may be reduced; and impairment of hepatic function has been reported.

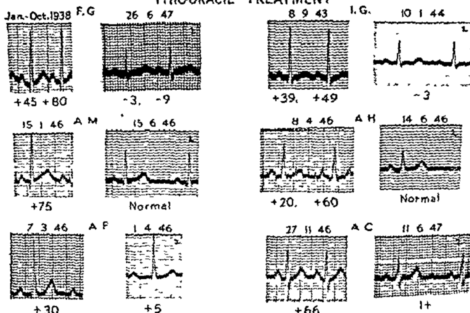


Fig 18·06—Electrocardiograms (all lead 2) showing relatively high voltage P and QRS waves in 6 cases of thyrotoxicosis After treatment with thiouracil the voltage falls considerably The B M R is recorded under each record

SPECIAL INVESTIGATIONS

1. *The basal metabolic rate* (B M R.), introduced by Magnus-Levy in 1895, has proved a useful guide to the degree of hyperthyroidism, and is a measurement of the amount of oxygen consumed by the patient per minute when at complete rest, i e fourteen hours after the last meal, and after lying down undisturbed for at least half an hour. The patient breathes in and out of a closed system containing equal proportions of air and oxygen for ten minutes, carbon dioxide being removed by means of soda-lime; the amount of gas disappearing from the system represents the total amount of oxygen consumed This is then recorded in terms of oxygen consumption per square metre of body surface per minute, and expressed as a percentage of what a normal person of the same age and sex would require In thyrotoxicosis, the B.M.R. commonly ranges between plus 10 and plus 80 per cent. Read's formula for estimating the B M.R. by the pulse rate and pulse pressure is unreliable, and worth no more than the knowledge that the com-

bination of tachycardia and a bounding pulse suggest a raised cardiac output. (Read's formula is: B M.R. equals $\frac{3}{4}$ [pulse rate plus $\frac{3}{4}$ pulse pressure] minus 72.)

It should be understood that a single B M R. of plus 20 per cent does not necessarily mean that the disease is milder than one with a B M.R of plus 40 per cent, for the course of thyrotoxicosis is variable. Serial readings may give a truer picture of the degree of activity. Another important point is that auricular fibrillation and heart failure are more often associated with low grade activity acting over a long period of time, than with acute thyrotoxicosis, so that the level of the B M.R. is no guide to the degree of cardiac disability

The B M.R. is more difficult to interpret when measured for diagnostic purposes, but if it is below plus 10 per cent thyrotoxicosis is improbable High readings, however, may be due to faulty basal conditions or to other causes, such as leukæmia, and relatively high readings may be obtained in congestive heart failure of any etiology

2. *The administration of* 10 *minims* (0.6 *ml.*) *of Lugol's iodine* three times daily for a week or ten days, may be used as a test for hyperthyroidism in two ways: (1) to see whether it unmasks a goitre, for a hyperplastic gland enlarges and hardens under its influence; (2) to determine its effect on the sleeping pulse, body weight, and B M.R, for these are beneficially influenced in thyrotoxic cases, but not when the B M R is raised from other causes

3. *Measurements of the cardiac output, peripheral blood flow, and circulation time* provide valuable data Outputs of 6 to 12 litres per minute are usual, and are correlated more with the heart rate than with the venous filling pressure When the heart fails, the output drops, usually to subnormal levels. The fore-arm blood flow is invariably increased, and usually remains so when the cardiac output falls as a result of failure, moreover, the augmented flow does not subside for several weeks after the B M.R has been restored to normal by means of thyroidectomy or thiouracil therapy (Howarth, 1948). Circulation times under 10 seconds are characteristic (Goldberg, 1938) and may remain well within normal limits when there is systemic congestion

The demonstration of a high cardiac output at rest places a case in the hyperkinetic group: the differential diagnosis then includes severe anæmia, anoxic cor pulmonale, arterio-venous aneurysm, Paget's disease of bone, secondary carcinoma involving the liver or other serious hepatic disorders, and beri-beri The majority of these can be recognised or excluded at once on clinical grounds

4 *Urinary creatine test* Up to 200 mg of creatine may be excreted daily in the urine by normal women and children in an irregular manner, but very little, if any, by normal men Excessive creatinuria occurs during pregnancy, and increased amounts may appear in the urine of either sex in fevers, wasting diseases and certain muscular dystrophies

Most thyrotoxic subjects excrete an excess of creatine (Sohval, King and Reiner, 1938), and its detection may be used as a diagnostic test if the above considerations are borne in mind. Thyroid responsibility may be proved by the disappearance of creatinuria within ten days of first giving iodine or thiouracil treatment (fig 18 07) (Schrire, 1938). On the other

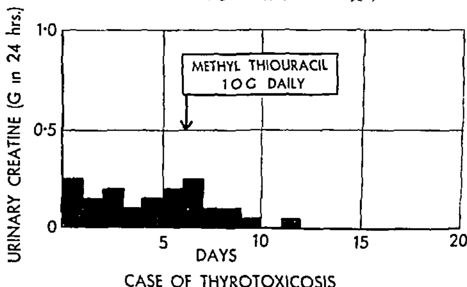


Fig 18 07—Effect of thiouracil on the excretion of creatine in the urine

hand, absence of creatinuria does not exclude thyrotoxic heart disease, for such case
long peri
creatine e

5 *Electrocardiography* may reveal abnormally high voltage of P and QRS (fig 18 06) as previously stated. It may also be of value in proving the nature of an irregularity of rhythm, or in excluding certain other causes of a hyperkinetic circulation (e.g pulmonary heart disease and anæmia)

6 *Radio-active tracer iodine* may be used to estimate the rate at which it enters and leaves the gland (Keating *et al.*, 1945) In thyrotoxicosis iodine is concentrated in the gland more quickly and in greater degree than in normal controls; and the excretion of iodine in the urine (after a test dose) is retarded A Geiger counter is placed on the neck to detect the arrival and concentration of tracer iodine in the thyroid, and a liquid counter is used to detect it in the urine. These tests are promising and may become of service to the clinician

TREATMENT

The most satisfactory method of treating thyrotoxic heart disease is subtotal thyroidectomy as developed by Dunhill (1908, 1929, 1937). The best results are obtained when physician and surgeon work in the closest

harmony, success depending as much upon the skill and judgment of the physician as upon the experience and dexterity of the surgeon (Fraser and Dunhill, 1934), adequate premedication being all-important

The patient should be put to bed, and fed on a liberal and nourishing diet The addition of 5 to 10 mg. of aneurin daily may be helpful on the grounds that an abundant supply of this vitamin is needed for the increased carbohydrate metabolism. Fatigue and weakness may respond to 50 mg of pyridoxine daily (Soskin and Levine, 1944) Phenobarbitone, ½ a grain (32 mg.) t.d s , or potassium bromide, 10 grains (0 64 G) t d s , may also be prescribed with benefit, and a nocturnal sedative is usually necessary

During this preliminary stage of treatment, which usually induces some remission of symptoms, the degree of thyrotoxicosis may be assessed clinically and by means of the special tests detailed above Iodine may then be given by mouth in doses of 10 minims (0 6 ml.) of Lugol's solution three times daily, preferably in milk. Within ten days there is usually marked improvement: the pulse rate falls, the B M.R. is lowered, and the patient feels better (Waller, 1914; Plummer, 1923) The moment for operation is usually ten to fourteen days after beginning iodine If, however, the patient is not ready at that time there should be no hesitation in postponing it, but the dose of iodine should then be reduced to 5 minims (0 3 ml) three times a day (Fraser and Dunhill, 1934)

The introduction of thiouracil by Astwood (1943) following the discovery by the Mackenzies (1941) that the administration of sulphaguanidine to rats caused thyroid hyperplasia and reduction of colloid, has proved an important therapeutic advance. Thyroid hyperplasia was attributed to increased production of thyrotropic hormone by the anterior pituitary in an endeavour to compensate for deficiency of thyroid hormone brought about by sulphaguanidine. Astwood found that many substances had a similar effect, including all the sulphonamides, *p*-aminobenzoic acid, thiourea, and its compounds; and that of these, thiouracil offered the best prospects, being potent and relatively non-toxic It is held that thiouracil and the other substances mentioned act by interfering with the union of iodine and tyrosine and so prevent the formation of di-iodotyrosine, a known precursor of thyroxine (Riker and Wescoe, 1945) The histological appearance of the thyroid gland under their influence resembles the hyperplastic gland of iodine deficiency

Extensive trials have established the dosage, toxic effects, and early results of thiouracil treatment on firm ground (Astwood, 1944, Williams, 1944) Reduction of the B.M R and amelioration of all symptoms, except exophthalmos and those due to pressure from the goitre, are obtained whether the hyperthyroidism is due to primary Graves' disease or to toxic nodular goitre. The usual dose is 0 2 G of thiouracil twice daily for about three weeks, or until the available evidence suggests that the production of thyroid hormone has been reduced to normal levels During this stage the white blood cells may be counted weekly, and the patient is

best confined to bed in hospital. If medical treatment is continued, the dose is then reduced to 0.2 G. daily for a month or so, and the patient is allowed to resume her normal activities. Next, the maintenance dose is discovered by trial and error; it varies considerably from case to case, but is of the order of 0.05 to 0.2 G. daily. According to Himsworth (1948), equally good results are obtained when the initial dose is only 200 mg. daily, and the maintenance dose 50 to 100 mg. Himsworth claims that the results of thiouracil therapy are as good as those of subtotal thyroidectomy, and that medical treatment should therefore be preferred because the mortality rate is lower. Auricular fibrillation may revert to normal rhythm spontaneously with thiouracil treatment, or normal rhythm may be restored by means of quinidine. Treatment should be continued for at least twelve months if medical cure is desired; but even then 33 to 50 per cent of cases relapse when the drug is withdrawn (Himsworth, 1948; Williams, 1946).

Signs and symptoms of myxœdema may develop if too much thiouracil is given, but soon disappear when the dose is reduced. Toxic reactions occur in 13 per cent of cases (Van Winkle, 1946), usually during the first three weeks, and include nausea and vomiting, sulphonamide-like rashes, fever, agranulocytosis, purpura and adenopathy. The most serious of these is agranulocytosis (1 to 2 per cent) which should be treated promptly with penicillin, pentnucleotide, liver extract, and perhaps blood transfusion, thiouracil being abandoned. An uncontrollable hæmorrhagic state ending in renal failure was the cause of death in one case known to the author. The mortality rate has been about 0.5 per cent (Moore, 1946), but may be less now that physicians are more experienced in using the drug. Aminothiazol, 0.2 to 0.8 G. daily (Perrault, 1946), has been used widely in France, but has little advantage over thiouracil. Methyl thiouracil in similar doses is less toxic and propyl thiouracil least so, both are as potent as thiouracil (Astwood and VanderLaan, 1945).

In view of the high relapse rate on discontinuing thiouracil treatment, and because the operative risk and difficulties may then be greater owing to the increased vascularity of the gland, most workers favour the drug mainly as a preliminary to partial thyroidectomy. Moreover, thiouracil has not replaced iodine in this respect; for the subsequent administration of Lugol's solution is found to diminish the vascularity of the gland and so to facilitate the operation (Means, 1946). Again, in most cases of primary Graves' disease pre-operative iodine is so satisfactory that thiouracil is hardly justified. But in severely toxic cases, and in most instances of toxic nodular goitre with or without cardiac embarrassment, thiouracil is superior to iodine. They may be given together with advantage in doses of 0.1 G.–0.2 G. of methyl or propyl thiouracil and 5 minims (0.3 ml.) of Lugol's iodine three times daily. Symptoms should be controlled within two weeks. Subtotal thyroidectomy may then be carried out when convenient; there is no urgency, as there is when iodine is used alone, because patients do not relapse while taking sufficient thiouracil.

Cardiac complications do not contraindicate partial thyroidectomy (Dunhill, 1937). More careful preparation, however, is needed, auricular fibrillation must be controlled and heart failure relieved before it is safe to operate, but normal rhythm should not be deliberately restored at this stage

The commonest post-operative complication has been paroxysmal auricular fibrillation with rapid ventricular rate, but this may be less frequent if the patient is prepared with thiouracil. It should not occasion undue alarm, for the rhythm usually reverts spontaneously to normal within 48 hours If auricular fibrillation persists, however, whether previously well established or of recent onset, every effort should be made to restore normal rhythm by means of quinidine before the patient leaves hospital (see page 149). The risk of embolism is slight, perhaps because the hyperkinetic circulation lessens the chance of venous thrombosis

More recently, attempts have been made to treat toxic goitre with a combination of thiouracil and thyroxin. It has been pointed out that exophthalmos and the size and vascularity of the goitre may be increased by thiouracil, and have been attributed to the liberation of increased quantities of thyrotropic substance owing to deficiency of thyroid hormone Although hyperthyroidism obviously cannot result from this thyrotropic activity, proper cure of the disease may well be frustrated by its presence Moreover, the vascularity of the gland may become so great that it may function as an arteriovenous aneurysm, and so maintain the hyperkinetic circulation thiouracil was meant to relieve A continuous thrill and loud machinery murmur may then be appreciated over the gland In one such case investigated by Wyndham and the author, admittedly the result of overdosage, the resting cardiac output was twelve litres per minute But if a maintenance dose of thyroid (1 to 3 grains or 60 to 180 mg daily) is given in conjunction with thiouracil, pituitary hyper-activity may be prevented or may subside if already present (Williams and Bissell, 1943) It is possible that medical cure may be more readily achieved along these lines.

Three other methods of treatment may be mentioned 1 *X-ray therapy* is curative in about a third, results in some improvement in a third, and is without benefit in the remainder (Means and Holmes, 1923) It may be useful in thiouracil-sensitive subjects who refuse operation 2 *Pituitary irradiation* has been tried with limited success (Thompson and Thompson, 1944), but not very widely Interference with other pituitary functions is the obvious disadvantage, even if greater antithyrotropic success were achieved 3 Preliminary reports on treatment with *radio-active iodine* have been favourable (Hertz and Roberts, 1942–6) As the substance is largely concentrated in the thyroid gland, the irradiation effect is considerable, but the difficulty in gauging the correct dose, and the danger of exciting malignant changes in the gland are possible drawbacks

Thyrotoxic crises Owing to the impossibility of neutralising thyroid hormone that has already been manufactured, both iodine and thiouracil do

not benefit the patient for several days (graphs illustrating the effect of partial thyroidectomy, iodine and thiouracil on the basal metabolic rate are remarkably similar). The treatment of thyrotoxic crises by massive doses of iodine (by mouth or intravenously) as advocated by Boland and Kepler (1938), for example, is therefore questionable. Absolute rest, heavy sedation, and replacement of salt and water lost in sweating and vomiting, are probably more important Aneurin, 100 mg. intravenously, may also help

If toxic goitre is recognised and treated promptly, however, crises should not occur

Thyrotoxicosis and tonsillitis Cases are encountered in which an attack or repeated attacks of tonsillitis are associated with thyrotoxicosis. The problem then arises whether to perform partial thyroidectomy or tonsillectomy first Before the introduction of thiouracil most authorities agreed that it was safer to remove the thyroid gland before the tonsils, for tonsillectomy in thyrotoxic patients sometimes precipitated a crisis. Thiouracil has simplified the problem, however, and allows tonsillectomy to be undertaken first without risk



Fig 18 08—Skiagram showing gross cardiac enlargement in a case of thyrotoxicosis plus mitral stenosis.

Thyrotoxicosis and rheumatic heart disease Thyrotoxicosis may be associated with acute rheumatic carditis or with established rheumatic valve lesions Both Parry's and Basedow's first cases were so related. The association, if more than a coincidence, is indirect, and may depend upon their joint relationship to streptococcal tonsillitis Treatment aims at partial thyroidectomy as soon as the rheumatic state allows it Rheumatic heart disease with fixed valve lesions may result in enormous enlargement of the heart owing to the excessive work induced by thyrotoxicosis (fig 18.08), and the sooner the latter is treated the better. Total thyroid ablation, however, is not indicated

Thyrotoxicosis and hypertension. There is a group of cases, sometimes designated thyrotoxic hypertension, in which thyrotoxicosis is associated with high blood pressure, both systolic and diastolic levels being raised. There is little evidence of any direct relationship between the two diseases, and the blood pressure does not fall following thyroidectomy (Bisgard, 1939)

Thyrotoxicosis and angina pectoris. Ischæmic heart pain occurs when the blood supply to the myocardium is insufficient to meet the demand By increasing the demand, thyrotoxicosis may induce angina in a patient with a relatively minor degree of coronary atherosclerosis, behaving in this respect like anæmia Thyroid hormone also sensitises the organism to adrenalin. When ischæmic and thyrotoxic heart disease are associated, subtotal thyroidectomy need not be withheld on the grounds of undue risk, for the operation may be followed by many years of normal life before angina again makes its appearance.

Thyrotoxicosis and pregnancy Thyrotoxicosis developing during pregnancy may be due to primary exophthalmic or nodular goitre With the aid of thiouracil, in combination with small doses of iodine or thyroid, patients should be taken safely to term If the condition does not then subside, subtotal thyroidectomy may be carried out. The danger of goitre developing in the fœtus is minimised by the iodine (or thyroid); but it is well to keep the dose of thiouracil as small as possible (not more than 0 2 G. daily).

PROGNOSIS

There are few forms of heart disease that respond better to adequate treatment than thyrotoxic heart disease. Cases with gross congestive failure and well established auricular fibrillation may be cured, and the largest hearts may resume their normal size (fig 18 09) On the other hand, heart failure and death are inevitable if the disease remains unchecked In the



Fig 18 09 (a)—Thyrotoxic heart failure



(b)—After subtotal thyroidectomy

hands of the best surgeons the mortality rate of subtotal thyroidectomy in cases of toxic nodular goitre has been 1.6 per cent (Cole, 1944) to 2.6 per cent (Dunhill, 1937), but it may be less with thiouracil preparation. No reliable figures are available upon which to assess the total relapse rate. Post-operative tetany and paralysis of the vocal cord each occurs in approximately 1 per cent (Means, 1946)

According to Himsworth (1948), there is a 3 : 1 chance in favour of a permanent remission with thiouracil treatment.

THE HEART IN MYXŒDEMA

Artificial myxœdema, produced by total ablation of the thyroid gland or by thiouracil, benefits the heart by lessening the circulatory demands, and so relieves angina pectoris and congestive heart failure Yet well developed myxœdema from natural causes gives rise to cardiac enlargement, pericardial effusion, and ultimately to congestive heart failure; moreover, angina pectoris may be associated Enlargement cannot be due to overwork; it must depend upon some intrinsic change in the heart muscle Histological examination, however, is usually disappointing The fault is probably biochemical, and is unlikely to be properly understood until studies in tissue chemistry are more advanced

The diagnosis of myxœdema is suggested by the placid sleepy character (unless there is manic psychosis), poor memory, sensitivity to cold (Raynaud's phenomenon is common), dry coarse skin, thickened lips and tongue, low thick voice, baggy eyes, scanty dry hair, podgy hands, supraclavicular pads of fat, and general pallor. It is confirmed by an impalpable thyroid gland, by a B.M R of minus 30 to 40 per cent, by prolongation of the arm-to-tongue circulation time to 19 to 25 seconds, by a high blood cholesterol of 300 to 400 mg per cent, by relative insensitivity to atropine and adrenaline, by a characteristic form of anæmia, and by a pathognomonic electrocardiogram

The type of anæmia which responds to thyroxine alone is normocytic and orthochromic, and may be regarded as a compensatory adjustment to diminished oxygen requirement (Bomford, 1938). The electrocardiogram shows sinus bradycardia, low voltage auricular and ventricular complexes, and flat or inverted T waves in all leads (fig. 18 10) The cause of these changes is not yet understood. they do not depend upon the presence of pericardial effusion, nor upon the state of the subcutaneous tissues. The response to thyroxine is quick and complete, and accompanies beneficial changes in the B M.R. The electrocardiogram in cretinism behaves similarly (fig. 18 11).

Whilst a well developed case of myxœdema is difficult to overlook (fig. 18.12), cases of short duration, especially in younger women (the sex incidence is 8 : 1 in favour of women), may easily escape notice The diagnosis should be considered in any case of congestive heart failure or of peri-

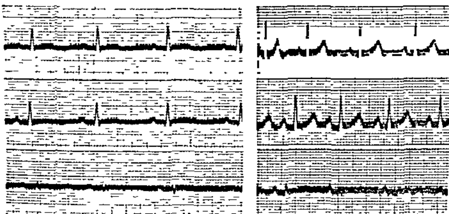


Fig 18 10 (a)—Electrocardiogram showing sinus bradycardia, low voltage auricular and ventricular complexes and flat T waves in all leads in a case of myxœdema
(b) Normal electrocardiogram after treatment

cardial effusion of unknown etiology. Congestion, when it occurs, is systemic, and is associated with a low cardiac output Pericardial effusion is due to simple transudation. Cardiac enlargement is general (fig 18 13), and pulsation of all chambers is poor Angina pectoris is said to occur in 1 to 2 per cent of cases (Smyth, 1938), but is probably more frequent Coronary atherosclerosis may result from the high blood cholesterol

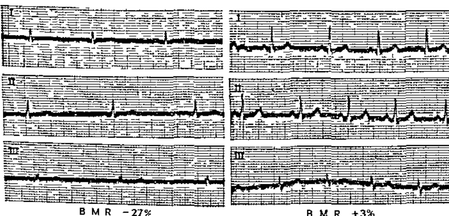


Fig 18 11—Electrocardiogram before and after treatment in a case of cretinism

Myocardial infarction without coronary thrombosis has been described in such cases when treated too vigorously with thyroxine. The blood pressure is little influenced by myxœdema, and is as often elevated as low When congestive failure is present, measurements of the B M R. give unduly high readings, more reliance should then be placed on other tests, especially on the electrocardiogram



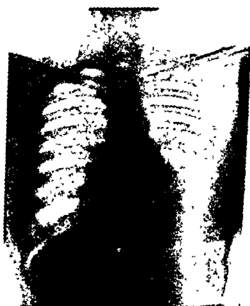
Fig 18 12 (a)—Myxœdema



(b) After seven weeks' treatment



Fig 18 13 (a)—Skiagram showing general enlargement of the heart in a case of myxœdema



(b) After treatment

Treatment. If there is no evidence of coronary disease, thyroxine may be given intravenously in a single dose of 10 mg., or thyroid may be given by mouth in doses of 3 grains (0.2 G.) daily. The response is delayed but dramatic. Within five to ten days the B.M.R. rises, the blood cholesterol falls, T wave changes are corrected, and clinical improvement is obvious. Signs of failure or of pericardial effusion soon disappear, and the heart resumes its normal size (Lerman, Clark and Means, 1933).

Initial treatment is easier than maintenance. With the aid of the B.M.R. it is not difficult to regulate dosage for a patient at rest in bed, but when she leaves hospital and varies her activities, it is not so easy, and supervision is required for life. The average maintenance dose of thyroid extract is 2 to 3 grains (0.13 to 0.2 G.) daily by mouth.

If there is any suspicion of associated coronary disease, initial treatment should be cautious, and the oral route advised. Not more than 1 grain (65 mg.) of thyroid extract should be given daily, and in cases with angina pectoris not more than ½ a grain (32 mg.). The dose may be increased slowly, week by week, if well tolerated, or reduced and maintained at a minimum if not tolerated.

The chief complication arising during treatment is the development of angina pectoris. Should this occur the dose of thyroid may have to be less than ideal but enough to keep the blood cholesterol below 300 mg. per cent.

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CHAPTER XIX

HYPERKINETIC CIRCULATORY STATES

(ANÆMIA, PREGNANCY, ARTERIO-VENOUS ANEURYSM, BERI-BERI, PAGET'S DISEASE OF BONE, HEPATIC FAILURE)

IN addition to the diseases enumerated above, hyperkinetic circulatory states (Harrison, 1935) include thyrotoxicosis, anoxic pulmonary heart disease, fever and exercise The first two have been considered fully elsewhere, and the last two have a purely physiological basis.

All these conditions are characterised by a raised cardiac output maintained by means of tachycardia, a raised venous filling pressure, or both, moreover the heart may beat more strongly. Conspicuous evidence of vasodilatation in skin and muscle is found in all of them the skin is warm and flushed, the pulse is collapsing, the digital vessels throb, and there may be capillary pulsation, in fact the peripheral circulation resembles that seen in aortic incompetence The fore-arm and calf blood flows are also increased Whilst young and healthy hearts may cope with the situation without distress, older or unhealthy hearts may fail to meet the requirements

It may be difficult clinically to recognise congestive failure in these cases, for the usual signs may have other interpretations Thus, a raised venous pressure may be part of the physiological mechanism maintaining a high cardiac output (McMichael, 1947), enlargement of the liver may be due to secondary carcinoma or to hepatitis, and œdema is commonplace in severe anæmia and beri-beri for other reasons Indeed, it is by no means easy to be sure what is meant by failure in this group, for example, McMichael uses the term "high output failure" to describe a state in which a raised venous pressure and œdema are associated with a high cardiac output, whether or not the latter is capable of being raised further. Yet failure ordinarily denotes an overloaded heart or ventricle, one incapable of raising its output further. But this question has already been discussed (page 155)

THE HEART IN ANÆMIA

Physiology Severe chronic or post-hæmorrhagic anæmia may affect the heart in three ways: (i) it may cause a hyperkinetic circulatory state as already described; (ii) it may cause or precipitate angina pectoris or acute coronary insufficiency; (iii) it may result in nutritional degenerative changes in the cardiac muscle, which may reduce its reserve

With an oxygen consumption of 240 ml per minute, an anæmic subject with a hæmoglobin of 20 per cent could not have a cardiac output less than 6 litres per minute if all the available oxygen were utilised (20 per cent Hb.=3 G. Hb per cent=3×1.34 ml oxygen per cent 4 ml oxygen per cent or 40 ml. per litre. Thus cardiac output = $\frac{240}{40}$ 6 litres per minute) If half the available oxygen were utilised the cardiac output would be 12 litres per minute.

In anæmic subjects investigations have shown that the resting cardiac output may reach 13 litres per minute and utilisation of available oxygen may be increased from the normal 33 per cent to as much as 90 per cent (Liljestrand and Stenstrom, 1925–6; Nielson, 1934, Sharpey-Schafer, 1944) These changes do not occur at rest with hæmoglobin values above 50 per cent, but become increasingly apparent at lower levels (Bouchut and Froment, 1934) The high cardiac output is maintained both by tachycardia and a raised venous pressure The latter must be due to widespread capillary or peripheral venoconstriction, for the blood volume is reduced (McMichael *et al.*, 1943), and the small arteries and arterioles are dilated (McMichael, 1947).

Clinical features The chief symptoms of severe anæmia are breathlessness, fatigue and palpitations Angina pectoris occurs in about 30 per cent (Coombs, 1926; Pickering and Wayne, 1934), occasionally even when there is no underlying coronary disease Thus the author has treated a boy of 17 with pernicious anæmia and angina pectoris, and also a young man of 21 who presented himself with classical ischæmic heart pain due to iron deficiency anæmia resulting from bleeding hæmorrhoids Œdema may be due to congestive heart failure, but is more often nutritional It is especially prone to develop during the first three weeks of blood regeneration in response to treatment of the anæmia

Paroxysmal cardiac dyspnœa or acute pulmonary œdema is rare as a spontaneous event, but may arise during blood transfusion or saline infusion. These procedures should not be lightly undertaken in cases of severe chronic or post-hæmorrhagic anæmia· precautionary measures include the use of concentrated red cells instead of whole blood, and venous pressure lowering agents, such as cuffs applied to the thighs Transfusion should be temporarily abandoned if the venous pressure is seen to rise appreciably.

Physical signs. A hyperkinetic circulation and peripheral vasodilatation may be recognised by the features detailed previously.

A functional systolic murmur (so-called hæmic murmur) at apex or base is common, and is probably due to mitral incompetence resulting from left ventricular dilatation or to the increased velocity of blood flow Functional mitral or aortic diastolic murmurs may also be heard occasionally, earlier observations such as those by Von Noorden (1891), Sahli (1895) and Kraus (1905), having been amply and repeatedly confirmed (Goldstein and Boas,

1927) Mitral presystolic or diastolic murmurs are probably due directly or indirectly to the increased velocity of blood flow, the mechanism being almost certainly the same as that responsible for mitral diastolic murmurs in patent ductus arteriosus, ventricular septal defect and thyrotoxicosis Basal diastolic murmurs are probably due to dilatation of the aortic or pulmonary rings

The electrocardiogram. Despite several publications emphasising the normality of the electrocardiogram in anæmia (e g Smith, 1933; Pickering and Wayne, 1934), there can be no doubt that significant changes occur in at

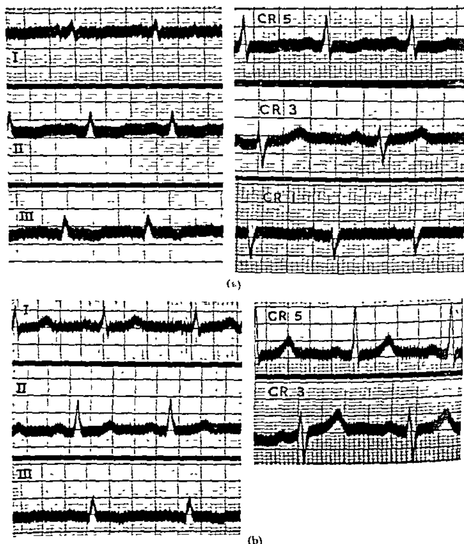


Fig 19 01—Electrocardiogram showing low voltage and flat or inverted T wave in all leads in a case of pernicious anæmia
(a) Before treatment
(b) After correction



Fig 19 02—Electrocardiogram showing depression of the ST segment due to acute coronary insufficiency resulting from post-hæmorrhagic anæmia



(a) Before treatment



(b) After treatment of the anæmia

Fig 19 03—Skiagram showing general cardiac enlargement in a case of severe pernicious anæmia

least a third of cases with hæmoglobin values under 40 per cent (Block, 1937) In a consecutive series of twenty such cases analysed by the author, eight showed low voltage, depressed S-T segments, or flat or inverted T waves in left ventricular surface leads or their equivalents As the anæmia improved under treatment these faults were corrected (fig. 19.01). Several instances of bundle branch block have also been observed, but these have always persisted when the anæmia was cured. Depression of the S-T segment is common following gross hæmorrhage, and is believed to represent temporary coronary insufficiency (fig 19.02)

Fluoroscopy X-rays often reveal slight enlargement of all chambers of the heart and prominence of both the aorta and pulmonary artery in cases with hæmoglobin levels below 40 per cent (fig. 19 03)

Necropsy studies have revealed slight increase of heart weight (350 to 450 G) in the majority of cases of severe anæmia, and considerable inc[illegible] occasionally (Cabot and Richardson, *1919*). Experimental anæmia [illegible] cardiac hypertrophy at hæmoglobin levels of [illegible] least twice normal) at levels [illegible] 930–1). According to Grunberg (1930), hypertrophy is [illegible] when the hæmoglobin is 15 per cent or less, and does not occur at all when the hæmoglobin is 66 per cent or more

These findings harmonise with the behaviour of the cardiac output in relation to hæmoglobin levels, and there can be little doubt that enlargement depends on increased work

Clinical diagnosis Knowledge of cardiovascular behaviour is of little value in making a diagnosis of anæmia, and is of no value at all in determining the nature of the anæmia. It is helpful, however, in differential diagnosis, especially between anæmia, the anxiety states, and bacterial endocarditis Thus, an anxiety state may present with the same group of symptoms, including pallor, and there may be cardiac over-action and functional systolic murmurs The pallor, however, is due to peripheral vasoconstriction, and does not affect the conjunctivæ or the mucous membranes, and it is less obvious in the palms of the hands; the nail beds too are more likely to be cyanosed than pale In anæmia, pallor is often waxy, chalky, or lemon tinted according to its severity and type. The cardiovascular dynamics are quite different Over-action of the heart and tachycardia in the anxiety states are associated with little or no rise in cardiac output, there is peripheral vasoconstriction rather than vasodilatation, and the diastolic blood pressure tends to be raised in casual readings, the stroke-volume tends to be reduced, and the pulse may be small; the circulation and venous pressure are normal

A type of case that may cause confusion is one that presents with pallor, low-grade fever, petechiæ, splenomegaly, over-action of the heart, and a loud systolic murmur at apex or base. Bacterial endocarditis may be suspected, especially when there is a diastolic basal murmur as well, and the

pulse is collapsing; yet all these features may be due to anæmia alone

Treatment. All cardiovascular changes due to anæmia are reversible, if the anæmia is treated successfully. Cardiac remedies are rarely required, apart from urgent measures in the event of acute pulmonary œdema (page 190). The danger of ill-judged or too rapid intravenous infusion has already been mentioned.

THE HEART IN PREGNANCY

Physiology. Changes in the cardiovascular system during normal pregnancy probably depend upon increased metabolism, raised intra-abdominal pressure, increase in blood volume, and upon the presence of a uterine

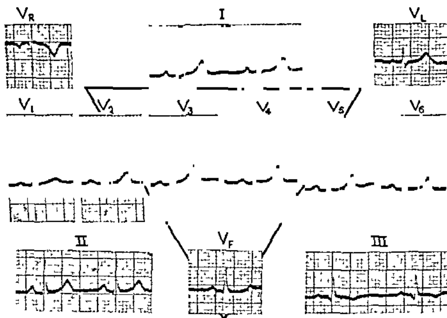


Fig 19 04—Electrocardiogram showing characteristic appearances associated with pregnancy

arterio-venous shunt The oxygen consumption increases by about 20 per cent, the cardiac output by about 50 per cent, the arterio-venous oxygen difference is decreased, and the pulse rate, pulse pressure, and venous pressure increased (Burwell *et al*, 1938) Faintness in the supine position may be due to pressure of the uterus on the inferior vena cava, so that blood is dammed back in the legs with a resulting fall in right auricular pressure Hot tingling extremities may be a reflection of increased peripheral blood flow.

Less important findings include functional systolic murmurs, ectopic beats, accentuation of the third heart sound, displacement of the apex beat

to the left and upwards, slight increase in the size of the heart, occasional minimal œdema, and a characteristic electrocardiogram showing a prominent S_1 and Q_3, inversion of T_3 (fig. 19 04), and a horizontal frontal plane vector

The changes described may begin as early as the second month, reach their maximum at about the end of the sixth month, and are maintained to term

The normal heart copes with the increased burden of pregnancy without difficulty, but diseased hearts may be in grave distress. The chief conditions that may give rise to anxiety are those that may affect women of child-bearing age, namely congenital, rheumatic, thyrotoxic, and hypertensive heart disease, and bacterial endocarditis

CONGENITAL HEART DISEASE

This is not hereditary, so there is no danger of its transmission to the fœtus

Patent ductus arteriosus and patent interventricular septum, unless gross, are no bar to pregnancy. Coarctation of the aorta usually causes little trouble, and is chiefly of interest because the associated hypertension may be mistaken for toxæmia of pregnancy, occasionally, however, the aorta has ruptured Atrial septal defect requires watching Relatively mild cases may be taken to term safely, but if right-sided enlargement is advanced, pregnancy should be prevented, or should be terminated in the first three months if possible The rise in right auricular pressure may cause reversal of the shunt and sudden severe cyanosis, or the increasing stress may precipitate right ventricular failure, which may also cause reversal of the shunt. Pulmonary stenosis is usually a direct bar to pregnancy, unless mild and of simple valvular type

RHEUMATIC HEART DISEASE

There are some who maintain that any woman who has rheumatic heart disease should be advised against having any children. They argue that pregnancy affects her adversely; that the strain of bringing up children shortens her life, and that her premature death leaves her family stranded at a critical time Others feel that to forfeit so much human happiness on these grounds is both undesirable and unnecessary. Is life so precious to prolong if so much of its meaning is taken away? Moreover, available modern statistics barely support the first argument. Thus in four combined series collected by Jensen (1938), the average age of death in spinsters or nulliparous women with mitral stenosis was 36 6, in married women with families it was 40 3. Again, Bunim and Rubricius (1948) could find no significant difference in the life histories of 169 rheumatic mothers and 215 rheumatic childless women Of course, the childless women may have been advised against pregnancy owing to the severity of their condition, so that the two groups may not be strictly comparable. there is insufficient

idence on this point. It is certain, however, that many women with mitral tenosis, unaware that there is anything wrong with them, have large amilies and lead normal lives, until the lesion is discovered in later life

The classification adopted by the New York Heart Association in 1924, whereby heart disease in pregnancy is divided into four grades, has proved elpful. Grade 1 is symptomless; grade 2 is subdivided into those with slight ymptoms (grade 2a) and those with more severe symptoms, but not yet aving congestive failure or auricular fibrillation (grade 2b), grade 3 signi-es auricular fibrillation or heart failure, past or present No restrictions re placed on women in grade 1. Women in grade 3 are strongly dissuaded rom pregnancy, and termination is usually advised if they are already regnant. Women in grade 2 may present more awkward problems

The chief difficulty arises out of the instability of the grading A woman tarting pregnancy in grade 2a, usually ends it in grade 2b. If she starts in rade 2b, she may later enter grade 3. All these cases must be carefully atched Any tendency towards increase of symptoms is met by increased est, even to complete rest in bed. In this way the great majority can be ept in their original grade. A woman in grade 2a should not be dissuaded rom pregnancy, but may be advised to limit her family to two or three

Women in grade 2b are usually warned against pregnancy If they have lready conceived, pregnancy should be terminated during the first three nonths If gestation is already between the third and sixth month, they hould be put to bed and observed for a week or two If they improve apidly and enter grade 2a, pregnancy is allowed to continue If they do ot improve, pregnancy should be terminated It must be borne in mind hat conditions steadily deteriorate up to the end of the sixth month, so hat a woman in grade 2b at the end of the fourth month, failing to respond dequately to sufficient rest, is almost certain to enter grade 3 in the sixth nonth Management of pregnancy after the sixth month when the patient s in grade 2b depends upon the history of the pregnancy, and the response o rest. If seen for the first time, and if previously physically active, such woman will surely enter grade 2a with rest in bed, and she may be taken afely to term But if already under observation, and receiving adequate est, further improvement cannot be expected, and the continued strain f the next three months may well induce auricular fibrillation or heart ailure She should remain strictly in bed if she improves she may be taken o term; if she remains problematical it is wise to terminate at the end of he eighth month; if she deteriorates, pregnancy should be terminated as oon as heart failure or auricular fibrillation are controlled

In a series of 546 cases of heart disease in pregnancy, of which 472 were heumatic, the respective mortality rates for class 3, 2b, 2a and 1 were 0 per cent, 4 7 per cent, 0 5 per cent and nil (Pardee, 1934) Hamilton 1947) reported more or less similar figures in a series of 1,335 cases, of vhich 93 per cent were rheumatic. When the cardiac findings were favour-ble (grades 1 and 2a) the mortality rate was 2 per cent and was the same

as in non-pregnant controls in the same category; when the cardiac findings were unfavourable (grades 2b and 3) the mortality was 18 per cent, compared with 6.7 per cent in non-pregnant controls. The infant mortality was 8.6 per cent in favourable cases, and 31 per cent in the unfavourable. When there was auricular fibrillation, the maternal mortality was 32 per cent (8 per cent in controls), and the infant mortality was 50 per cent. The most common causes of death in the unfavourable group were congestive heart failure (64 per cent) and embolism (13 per cent). Hamilton also noted that the mortality rate had increased slightly (from 16 to 18 per cent) since termination in the last trimester had been given up No difference in prognosis between cases of mitral stenosis and aortic incompetence was noted in any of the series mentioned

The risk of pregnancy in rheumatic cases does not end with the birth of the infant Pulmonary embolism in particular is more likely to occur during the puerperium

Cases of active rheumatic carditis are probably best terminated as soon as the state of the heart permits, for there is no knowing what the subsequent course will be, and a relapse later in pregnancy may prove very serious

When pregnancy is not advised, prevention is best insured by a simple sterilising operation Termination of pregnancy is by therapeutic abortion in the first three months, by abdominal hysterotomy from the fourth to the sixth month, by induced labour or by Cæsarean section during the seventh and eighth months, by natural means, or by Cæsarean section at term. The choice must rest with the obstetrician

BACTERIAL ENDOCARDITIS

Before the introduction of penicillin, the life of the fœtus was the main consideration The situation is now reversed, however, and every effort should be made to save the mother As heart failure is now the chief cause of death from bacterial endocarditis, termination of pregnancy may often be desirable

THYROTOXICOSIS

One of the few known factors that may aggravate or precipitate thyrotoxicosis is pregnancy It follows that thyrotoxic women should be advised against pregnancy until they are cured Improvement on rest and iodine, or as a result of thiouracil treatment, is not enough, such cases tend to relapse during pregnancy At least a year should pass after partial thyroidectomy or thiouracil cure before conception should be considered.

If a woman is thyrotoxic and already pregnant, therapeutic abortion should be considered during the first three months; if not seen until gestation is more advanced, it may be wiser to take the patient to term with the aid of thiouracil Subtotal thyroidectomy is better deferred owing to the risk of relapse The dose of thiouracil must be the minimum that is effec-

tive, for there is some danger of its causing goitre in the fœtus, the simultaneous administration of small doses of iodine or thyroid may prevent this (see page 493)

HYPERTENSION

High blood pressure discovered during pregnancy may be due to chronic persistent hypertension (usually essential) or to toxæmia of pregnancy Essential hypertension may be aggravated by pregnancy, but with rest, diet and sedatives mild cases can be taken to term Nevertheless, women with high basal blood pressures (above 160/100 mm Hg) should be advised against pregnancy in view of the increased risk of toxæmia, the high infant mortality (66 per cent according to Browne, 1947), and the chances of serious aggravation. For similar reasons pregnancy should be terminated in women with relatively high pressures in the first three months Hypertension associated with toxæmia of pregnancy is a separate problem and will not be considered here

ARTERIO-VENOUS ANEURYSM

Arterio-venous aneurysm may be congenital (circoid) or acquired (usually as a result of a perforating wound), and may occur in any situation, particularly in the brain, limbs or lung.

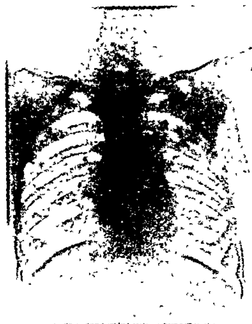
CONGENITAL CIRCOID ANEURYSM

Circoid aneurysm consists of a twisted mass of vessels in which arteries and veins are in direct communication. One or more superficial hæmangiomas may be seen elsewhere, or there may be a family history of such nævi

The cerebral type may give rise to epilepsy, to subarachnoid hæmorrhage,

saturation in samples of blood obtained from the ipsilateral jugular vein The lesion may be localised by means of angiography, 10 to 20 ml of 70 per cent diodone or other radio-opaque substance being injected rapidly into the carotid artery and skiagrams of the cerebral vessels being obtained at the appropriate moment The condition should be distinguished from berry aneurysm, and from Sturge's disease, in which facial and pial nævi without arterio-venous communications are associated with calcification of brain substance, epilepsy, mental retardation, and glaucoma (Nussey and Miller, 1939) Treatment consists of ligation of the common carotid artery on the side of the lesion, if after trial compression hemiplegia or other serious ischæmic symptoms do not occur. The risk of such an untoward event increases progressively with the age of the patient.

Circoid aneurysm in a limb presents similar features to those of its trau-





* Fig 19 05 (a)—Skiagram showing a congenital arterio-venous aneurysm of the lung. The appearances bear some resemblance to those of pulmonary tuberculosis

(b) Angiocardiogram showing diodone filling the aneurysm



* Fig 19 06—Calcification in the wall of an arterio-venous aneurysm.

* *Acknowledgements to Dr. Charles Baker*

matic cousin. It may be situated anywhere from the shoulder or pelvic girdle to the hand or foot. There is usually an increase in blood flow to the limb, which may be longer and larger than its fellow The veins stand out and may pulsate, and the skin temperature is raised It may be possible to locate the aneurysm with precision by observing the effect on the local and general circulation of compressing the various arteries of the limb at appropriate points An impressive machinery murmur and thrill may be appreciated over the aneurysm itself. Venous blood from the affected limb may be more saturated with oxygen than venous blood from the unaffected limb. The exact location and construction of the aneurysm may be demonstrated by means of angiography. Treatment is more difficult than in traumatic cases. Excision is usually impossible owing to the diffuse nature of the lesion, moreover, affected vessels are physiologically abnormal and fail to constrict when injured, so that severe and prolonged hæmorrhage may follow surgical interference. Ligation of the main vessels leading to the aneurysm (above and below) may be possible, but deep X-ray therapy is usually best.

Congenital arterio-venous aneurysm in the lung causes venous blood from the pulmonary artery to be shunted directly into the pulmonary veins and hence into the arterial circulation; at the same time the blood flow through the rest of lung may be reduced, the steep pressure gradient through the aneurysm offering the easier pathway. The result is a lowered arterial oxygen saturation in the region of 70 to 75 per cent (Burchell and Clagett, 1947), central cyanosis, polycythæmia and clubbing Most of the cases reported have been in children or young adults. Hæmoptysis has occurred in 50 per cent. The heart itself is normal, but there is often a continuous machinery murmur over the affected part of the lung. A skiagram may show a shadow not unlike local chronic pulmonary tuberculosis (fig 19 05a), but on fluoroscopy the lesion may be seen to pulsate, and angiocardiograms may show the abnormal vessels filled with diodone (fig 19 05b) Lesions may be single or multiple, and unilateral or bilateral Calcification may occur in the wall of an aneurysm (fig 19 06) One case (a girl aged 9) seen by the author died with cerebral abscess (see page 243) The condition should be distinguished from patent ductus arteriosus helping to correct pulmonary or tricuspid atresia. Treatment by lobectomy or pneumonectomy is curative unless there are several widely distributed aneurysms (Barnes *et al*, 1948)

ACQUIRED ARTERIO-VENOUS ANEURYSM

The great majority of acquired arterio-venous aneurysms are due to perforating gunshot wounds in war, and are seen most often in connexion with the femoral, brachial or carotid arteries. Occasionally they may be syphilitic, mycotic, or artificial Arterio-venous shunting may also occur in highly vascular structures, such as the thyroid gland in severe thyrotoxicosis or as a result of overdosage with thiouracil (page 493), the uterus in

pregnancy (page 507), and the bones in active Paget's disease (page 517).

The local signs and the effect on the general circulation are similar to those in congenital circoid aneurysm, but will be described more fully here because most investigations on the effects of arterio-venous shunting have been carried out on traumatic cases, usually with lesions in the thigh.

Local signs in the affected limb include fullness of the veins, increase of skin temperature, and sometimes œdema. On the other hand, peripheral ischæmic symptoms may predominate, and the toes may be unduly cold or even gangrenous (in cases of recent origin). A gross machinery murmur and thrill are invariable over the aneurysm The variability of the blood flow in the affected limb as judged by clinical criteria has been confirmed by Cohen, Edholm and others (1948), who found reduced flows distal to the lesion in two relatively recent cases, and an increased flow in a case of 29 years' duration. The blood flow in the unaffected limbs was normal.

The general circulation is hyperkinetic (page 502), and if the shunt is large enough, paroxysmal cardiac dyspnœa or signs of congestive heart failure may develop If the shunt is temporarily obliterated by digital compression of the femoral artery just above the lesion, the pulse rate falls 10 to 30 beats per minute (Branham's sign), the blood pressure rises 10 to 15 mm. Hg, the venous pressure falls slightly, and the cardiac output falls (Stead and Warren, 1945), but capillary pulsation is accentuated (Lewis and Drury, 1923). Slowing of the pulse may be due to the inhibiting effect of the abrupt although slight fall in right auricular pressure on the Bainbridge reflex, and is said to be abolished by 2 to 3 mg. of atropine (Kramer and Kahn, 1946)

Cardiac enlargement is almost certainly due to the raised cardiac output and increased stroke volume. The total blood volume is also increased in many cases (Holman, 1937) The hyperkinetic circulation is maintained by tachycardia and raised venous filling pressure, whilst the peripheral resistance is reduced by vasodilatation in skin and muscle.

Treatment. Any arterio-venous aneurysm large enough to influence the general circulation should be repaired. Smaller lesions may be left alone if causing no local symptoms, and some of them become obliterated spontaneously. Every effort should be made to repair the artery by lateral suture, with or without the aid of a covering strip of vein, so that the normal circulation is preserved (Junghanns, 1943). Ligation of artery and vein above and below the aneurysm is less satisfactory, the resulting circulation through the brain or limb being sometimes inadequate.

THE HEART AND CIRCULATION IN BERI-BERI

In modern civilised communities pure beri-beri is rare, the clinical picture being commonly influenced by deficiencies in vitamins other than aneurin (B_1) and by associated conditions, especially chronic alcoholism

Aneurin (thiamine), in association with other components of the vitamin B complex, is found chiefly in unpolished rice, Marmite, liver, yeast, wheat, and other grains. It is used by the body in carbohydrate metabolism, its chief known function being concerned with the oxidation of pyruvic acid which is formed from lactate When there is insufficient aneurin, carbo- [illegible] id [illegible] in [illegible] in that aneurin requirements are heavier. When, in addition, the vitamin B intake is reduced at the same time, as in chronic alcoholism, vomiting of pregnancy, and thyrotoxic crises, beri-beri may well develop

The normal requirement of aneurin is about 1 mg. daily for an adult, and is supplied adequately by the ordinary Europian diet Special ulcer diets, however, unless supplemented, may be deficient, and psychoneurotic patients with severe anorexia and vomiting may not receive a sufficient supply of the vitamin. Beri-beri was common in German concentration camps and Japanese prison camps during the second world war, although usually complicated by other vitamin deficiencies, and has always been relatively common in the Far East when the basic food has been polished rice

Aneurin deficiency is rarely gross in civilised communities, and so the presence of some additional factor is commonly needed before the effects of slight deficiencies are brought to light. Under these conditions beri-beri is atypical, for such patients are apt to be middle aged or elderly, and the classical signs may be masked by hypertension, coronary sclerosis, or emphysema Again, although beri-beri especially affects the right side of the heart in pure cases, it will affect the left side if left-sided stress is already present as in hypertension, or if the blood supply to the left ventricle is deficient as in occlusive coronary atherosclerosis Thus, in these mixed cases no clear picture of beri-beri develops (Konstam and Sinclair, 1940)

Behaviour of the heart and circulation The pure disease was studied in Java by Wenckebach (1928, 1934). The essential features included a hyperkinetic circulation, vasodilatation, enlargement of the right side of the heart, and dilatation of the pulmonary artery Few accurate cardiac output studies have been carried out, but the clinical description and the swift circulation time (Weiss and Wilkins, 1936–37) leave little doubt that it is high. Heart failure may develop suddenly, and fulminating cases occur in which death results within 24 to 48 hours of the alleged onset of symptoms (Hashimoto, 1937). Even in Great Britain, cases have been described in which heart failure has occurred remarkably suddenly and unexpectedly, leading to a rapidly fatal issue (Wood, 1939)

The cause of the hyperkinetic circulation is not yet clear. It may result from the same unidentified mechanism that ensures a high cardiac output to compensate for tissue hypoxia in anæmia and anoxic cor pulmonale; but instead of hypoxia there is faulty carbohydrate metabolism, and the high

... achieves *nothing* The drop in venous pressu... ...of 1 ml. of pitre... ...renaline (Wenck... ...be directly respon-sible by causing an arterio-venous ... ...h mechanism exis... is suggested by the sudden rise in pulse rate, venous pressure and cardi... output that may follow the subcutaneous injection of 10 mg of mecholi... which is known to cause vasodilatation in muscle.

The heart itself shows little specific at necropsy, the disturbance bei... biochemical, not structural

Diagnosis The clinical diagnosis of cardiovascular beri-beri rests on a... appropriate dietetic history, the demonstration of a hyperkinetic circula-tion, radiological appearances showing conspicuous dilatation of the pul-monary artery and right ventricle, electrocardiographic evidence of righ... ventricular stress, the response to pitressin and adrenaline, associated poly-neuritis, and on the finding of a raised blood pyruvic acid or reduce... amounts of aneurin in blood (Jansen, 1938, Sinclair, 1938) or urine (Harr... *et al.*, 1938; McAlpine and Hills, 1941)

Peripheral neuritis usually begins with pain in the calves on walking... similar in character to intermittent claudication. Associated weakness o... the legs, marked tenderness of the calves, numbness and tingling of th... fingers and toes, loss of deep tendon jerks, and glove and stocking anæs-thesia are usually found.

Evidence of deficiencies in other vitamins, especially of the vitamin B... group, is helpful in proving inadequacy of the diet

Treatment. It must be stressed that the symptoms of beri-beri may begin... abruptly, and that the course of the disease may be fulminating, death... occurring within a few days of the onset. Once the diagnosis has been made... there may be no time to lose. Again, the possibility of vitamin B_1 deficiency... should always be borne in mind in any case of heart failure of obscure... origin, especially when right sided Here is one of the fatal forms of hear... disease which is curable.

The patient should be put to bed immediately and aneurine hydro-chloride should be given at once intravenously in an initial dose of 50 to... 100 mg The effect is dramatic if not given too late. Subsequent doses... should be of the order of 10 to 20 mg. per day for a fortnight, orally or... parenterally, and followed by an adequate diet. An abundance of the other... components of the vitamin B group is also advised

Fulminating cases should benefit by repeated injections of pitressin (1... ml 4-hourly) until the vitamin has had time to work; but care must be... taken to avoid hydræmia by keeping the salt and water intake as low as... possible.

Chronic alcoholics, cases of severe thyrotoxicosis, Simmond's disease or... anorexic nervosa, and women vomiting in pregnancy, should be given 2 to... 5 mg. of aneurin daily as a precautionary measure.

PAGET'S DISEASE OF BONE

The hyperkinetic circulation associated with extensive active Paget's disease was first clearly demonstrated by Edholm, Howarth and McMichael in 1945. The general cardiovascular findings closely simulate those associated with arterio-venous aneurysm. In the case described by Edholm *et al.*, the blood flow through actively diseased bones was estimated to be 3 to 4 litres per minute, and the total cardiac output was 13 litres per minute. The venous pressure was elevated and there was dependent œdema Further observations on other cases of active Paget's disease have shown that the heart is not usually overloaded, for it is capable of increasing its output by means of tachycardia or a greater rise of venous filling pressure, on the other hand, paroxysmal cardiac dyspnœa may then occur (McMichael, 1947).

Paget's disease also encourages metastatic calcification, especially Monckeberg's sclerosis and calcification of the valve rings of the heart Extension to the interventricular septum may involve the bundle of His or its branches, with the production of complete heart block or bundle branch block respectively (Harrison and Lennox, 1948)

Cor pulmonale, secondary to thoracic deformity from Paget's disease, has also been described (Wilks, 1869)

Diagnosis If aortic incompetence and valve calcification are both present, the clinical diagnosis of Paget's disease may be overlooked in favour of atherosclerotic aortic valve disease. As long as the condition is borne in mind, however, diagnosis is easy, for skiagrams of the bones show characteristic changes and the blood alkaline phosphatase is very high

HEPATIC FAILURE

It is becoming increasingly evident that advanced disease of the liver may lead to a hyperkinetic circulatory state in addition to the well-known palmar flush and cutaneous spider nævi The usual cause is secondary carcinoma, but common cirrhosis and even serious infective hepatitis may be responsible. It appears that the liver normally detoxicates some vasodepressor substance, and that this substance accumulates when the organ is failing: vasodilatation results in certain territories, such as skin and muscle, and it is likely that arterio-venous communications open up and cause an extensive arterio-venous shunt. If unrecognised the situation may lead to embarrassing diagnostic error, the raised venous pressure, œdema and enlargement of the liver being readily attributed to heart failure.

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CHAPTER XX

TRAUMATIC LESIONS OF THE HEART AND GREAT VESSELS

SPONTANEOUS LESIONS

SPONTANEOUS traumatic lesions of the heart or great vessels include dissecting aneurysm of the aorta, rupture of a hypoplastic aorta or syphilitic aortic aneurysm, ruptured valve cusps in bacterial endocarditis, rupture of a congenital, syphilitic, or mycotic aneurysm of a sinus of Valsalva into the right side of the heart, rupture of chordæ tendineæ in rheumatic or bacterial endocarditis, and rupture or perforation of the heart or ventricular septum secondary to cardiac infarction or ventricular aneurysm The majority of such lesions have been described elsewhere as complications of the diseases mentioned Only dissecting aneurysm and rupture of an aneurysm of a sinus of Valsalva into the right side of the heart remain to be considered here.

DISSECTING ANEURYSM

Definition Dissecting aneurysm was so called by Lænnec (1826) and means dissection of the media of the aorta by extravasated blood that has penetrated between its coats from the vasa vasorum or from the lumen of the vessel

Incidence. About 1 per cent of all sudden deaths are due to dissecting aneurysm (Mote and Carr, 1942) Hospital records, which include relatively few such deaths, give an approximate incidence of one dissecting aneurysm in every 450 necropsies. Men are more susceptible than women in the ratio of 3 . 2 Patients are commonly between 50 and 60 years old, but 24 per cent are under 40 (Schnikter and Bayer, 1944), and a case has been recorded in a boy of 15 (Galbraith, Gardner and Hardwick, 1939) About 50 per cent of dissecting aneurysms in women have occurred during pregnancy (Schnikter and Bayer, 1944)

Etiology and pathology. Virchow's original conception that dissection follows an intimal tear at the site of an atheromatous ulcer is no longer tenable, for a tear at such a site is now known to be rare (Shennan, 1934) Although hypertension and atheroma are usually associated, they are not essential; the intima may be normal, and not even ruptured (Tyson, 1931)

Dissection is always within the media, commonly begins in the ascending aorta, and appears to be closely related to cystic medial necrosis (Erdheim, 1929) The cause of such necrosis is unknown, Tyson's thesis that it was due to obliterative endarteritis of the vasa vasorum has not been con-

firmed Cystic necrosis without dissection may be found sometimes in routine necropsies (Moritz, 1932; Rottino, 1939). Whether hæmorrhage into the diseased media commonly follows an intimal tear, or whether it comes from the vasa vasorum (the intimal tear then being due to secondary rupture), remains uncertain When the intima is intact, hæmorrhage obviously cannot come from the lumen of the aorta. On the other hand, intimal tears may undoubtedly be primary, for they may occur in healthy ascending aortas without subsequent dissection (Peery, 1942) Occasionally, hæmorrhage occurs into an area of cystic necrosis of the media without dissection, the hæmatoma then becoming organised and causing no trouble (Shennan, 1934)

Dissection may spread proximally and involve the root of the aorta, causing aortic incompetence, occasionally the coronary arteries are dissected and occluded Dissection usually spreads distally, however, may travel the whole length of the aorta, and may proceed along any of its branches Ischæmic effects from occluded visceral or parietal vessels are common The majority of cases die from external rupture, usually into the pericardium, sometimes into the left pleural cavity or elsewhere. Occasionally, dissection associated with an intimal tear in the ascending aorta ruptures back into the lumen of the vessel at some distal point, forming an alternative or double aortic channel (double-barrelled aorta). This is found in the majority of cases which recover (Shennan, 1934).

Clinical features. Dissection of the aorta may be precipitated by effort (Gager, 1928), and give rise to a well defined clinical picture with characteristic variations A typical attack begins suddenly with severe pain in the centre of the chest or in the praecordial area. The pain may be gripping, tearing, shooting, or vice-like, and usually lasts for hours, it may radiate to the head and neck, to the back—less often to the arms. Later in the attack it may spread to the lumbar regions or abdomen, and occasionally into the legs, depending on the extent of the dissection. In perhaps half the cases, however, pain is slight or absent (Baer and Goldburgh, 1948).

Breathlessness is nearly as common as pain, and syncope is not rare (Hamburger and Ferris, 1938). Attacks may therefore closely resemble coronary thrombosis, but in cases which survive the blood pressure usually remains high, and the electrocardiogram normal; moreover, dilatation of the aorta may often be seen in skiagrams (Wood, Pendergrass and Ostrum, 1932).

Other findings depend upon the site and extent of the dissection, upon which branches of the aorta are occluded, and upon the site of external rupture Aortic incompetence may develop when the root of the aorta is dissected (Weiss, 1935), and is being noted with increasing frequency (David *et al.*, 1947). myocardial infarction may occur if the left or right coronary artery is occluded, giving rise to the appropriate electrocardiographic pattern (Wainwright, 1944) Pericardial friction is heard occasionally, and hæmopericardium may be recognised before death.

Dissection of major arteries leads either to occlusion of the vessel, or to

increased amplitude of pulsation due to spontaneous periarterial sympathectomy (Weisman and Adams, 1944). Occlusion of one or other or both carotid arteries may cause hemiplegia, mental confusion or coma, of the anterior spinal artery, paraplegia; of arteries to the limbs, loss of the peripheral pulse and perhaps ischæmic pain; of the renal artery, hæmaturia —and so on Occasionally, a pulse that has been absent may re-appear as a result of rupture re-entry (Lawrence, 1935). A systolic murmur and thrill may develop over partly occluded vessels, including the aorta (McGeachy and Paullin, 1937). Left hæmothorax is found in about 12 per cent of cases (Baer and Goldburgh, 1948). Hæmorrhage into the mediastinum may be responsible for cough and dysphagia An abdominal mass may become palpable. Hæmoptysis, hæmatemesis and hæmaturia occur occasionally

Cases which survive the original dissection may present themselves later with congestive heart failure associated with aortic incompetence When there has been no history of pain, such cases have usually been diagnosed erroneously as syphilitic aortic incompetence, despite negative Wassermann reactions (Gouley and Anderson, 1940, Flaxman, 1942)

Finally, in differential diagnosis it should be remembered that fever and leucocytosis are the rule during the first few days, not the exception (Baer and Goldburgh, 1948).

Prognosis. According to Shennan (1934), about 10 per cent of all cases of dissecting aneurysm recover from the attack, usually owing to rupture re-entry. The majority succumb later to heart failure, either as a result of aortic incompetence or from associated hypertensive heart disease

Treatment. No treatment is likely to influence the course of dissection. Morphine should be given freely to combat pain If the patient survives the initial attack, he should be kept in bed for at least three weeks

RUPTURE OF AN ANEURYSM OF AN AORTIC SINUS (SINUS OF VALSALVA) INTO THE RIGHT VENTRICLE, RIGHT AURICLE OR PULMONARY ARTERY

Aneurysm of one of the aortic sinuses may be congenital, syphilitic or mycotic Rupture of such an aneurysm into the pericardium or left pleural cavity is immediately fatal, but perforation into the right auricle, ventricle or pulmonary artery leads to a well defined clinical syndrome which may be compatible with many years of active life

Incidence. The condition is rare, indeed, the author has only encountered and investigated four living instances Congenital cases may occur in young adults, syphilitic cases in later life, and mycotic at any age

Physiology Rupture into the right auricle causes a high pressure in that chamber, overloading of the right heart, and the rapid development of congestive failure Samples of blood obtained by means of cardiac catheterisation should be similar to those obtained in atrial septal defect (page 218) Perforation into the right ventricle may similarly overload the right



(a) Antero-posterior view, showing engorged pulmonary circulation, enlargement of the left ventricle, and resection of the 5th rib on the left side (the case having been operated on for patent ductus)



(b) Second oblique view showing enlargement of the left ventricle and dilatation of the pulmonary artery

Fig 20 01—Case of ruptured mycotic aneurysm of aortic sinus into the pulmonary artery

heart, blood samples and intracardiac pressures are similar to those in ventricular septal defect (R A P 0, R.V.P 17, P.A.P. 21 cm. saline; S V C. and R.A samples 44 to 45, R.V. and P.A samples 28 ml. O_2 unsat per litre in a case seen by the author.)

Perforation into the pulmonary artery sets up similar features to patent ductus arteriosus (fig. 20 01) In one such case investigated by the author, due to a perforated mycotic aneurysm from bacterial endocarditis (cured by penicillin), samples from the right auricle and ventricle showed 67 to 70 ml oxygen unsaturation per litre, whereas pulmonary artery samples were only 33 to 36 ml unsaturated. The mean right ventricular pressure was 40 to 43 cm of saline above the sternal angle, and the pulmonary artery pressure plus 86 cm.

Clinical features. Pain may occur from involvement of the orifice of one or other coronary arteries, but is otherwise absent. The onset is usually signalled by the rapid development of congestive heart failure, but not necessarily. The two cases mentioned above were by no means incapacitated, and had both lived seven years since the onset.

The chief signs are a loud machinery murmur, accompanied by a thrill, over the base of the heart, but at a lower level than that associated with

patent ductus arteriosus; accompanied by signs of aortic incompetence and by features resembling those of ventricular septal defect or patent ductus according to the site of the perforation

Prognosis. Rapid deterioration to a fatal outcome is said to be the rule, (Abbott, 1919), but this may be because the diagnosis is usually only made at autopsy. The author's four cases are not only alive but relatively well

EFFECTS OF DIRECT INJURY

Direct injury to the heart may be caused by stab or gunshot wounds, and very rarely by diagnostic procedures such as needling the pericardium The literature on the subject has been well surveyed by King (1941) and by Barber (1944).

GUNSHOT WOUNDS

A bullet or piece of shrapnel may perforate the heart through and through, may lodge in the myocardium or pericardium with or without perforation of one or more chambers, or may graze the surface of the heart without causing death In an analysis of 25 instances of war wounds involving the heart, made in conjunction with Nicholson in 1945, the relative incidence of such lesions was as follows·

Near misses	4
Grazes or tangential wounds	4
Through and through perforation	3
Foreign body in pericardium	7
Foreign body in myocardium	7

Of 1,640 consecutive penetrating chest wounds treated at Nicholson's centre, the heart was directly or indirectly injured in 1 7 per cent. The immediate result is hæmopericardium and the rapid development of cardiac tamponade If a foreign body passes close to the heart or lodges within half an inch of its surface, a transient pericardial serous effusion may develop. If the patient does not die from cardiac tamponade or hæmorrhage into the pleural cavity, complete recovery may follow, whether or not a metallic foreign body remains in the heart.

The chief complication during convalescence is recurrent acute pericarditis this is nearly always associated with the presence of a foreign body either in the pericardium or closely connected with it (Wood, 1945), it rarely arises when a bullet is embedded deeply in the myocardium. The attacks tend to be severe, with pain, fever, tachycardia, gross electrocardiographic changes, and the rapid development of a sterile serous effusion which may cause cardiac tamponade. They usually last about a week. The first attack may occur at any time during convalescence up to about three months after the injury, and may recur several times at intervals of about a month Of five such cases studied by the author in the second world war,

all finally recovered, three without interference and two after removal of the foreign body by Nicholson (1945).

A second complication is coronary thrombosis during convalescence, when a pericardial foreign body is lodged in contact with a major coronary vessel, but this was observed only once

Intravascular foreign body has been described on page 458.

Diagnosis. The possibility of cardiac injury should be considered in all cases of gunshot wounds of the trunk or neck, especially if the missile is judged to have been directed towards the heart, or if its direction is not known for certain. Early diagnosis depends upon recognising the signs of cardiac tamponade or hæmopericardium (page 345). An electrocardiogram may be most helpful by showing the presence or absence of the pericardial T_2 pattern.

Intracardiac or pericardial foreign body may be readily detected by means of fluoroscopy, but may be easily overlooked in skiagrams

Treatment It is impossible to say how many lives might be saved by early surgical repair of cardiac wounds In the second world war the majority of recognised cases survived without such early repair, or at least lived long enough to be evacuated to general hospitals; they were therefore all relatively favourable cases, and the great majority recovered.



Fig 20 02—Skiagram showing machine-gun bullet embedded in the wall of the right auricle

Relief of cardiac tamponade by paracentesis may be life-saving, both in the early stages or during a later attack of acute pericarditis Metallic foreign bodies lodged in the pericardium are best removed in view of the danger of recurrent pericarditis Although none of the attacks witnessed proved fatal, the episodes were most alarming. Intracardiac foreign bodies should probably be removed if superficial, and left alone if deep.

Prognosis. Only one of the twenty-five patients mentioned previously died, but as already stated these were favourable cases in that they had survived until evacuated to a general hospital.

Follow-up studies are incomplete, but the worst case, with three attacks of recurrent pericarditis and a machine gun bullet embedded in the wall

of the right auricle (fig. 20.02) was alive and well two years after being wounded.

In 1937, the author had the opportunity of investigating a healthy man with a machine gun bullet embedded in his heart since 1917 (fig. 20.03). This case was reported in detail by Grey Turner (1941). On the whole, it seems likely that the ultimate fate of these patients is favourable.



Fig 20 03—Skiagram showing machine-gun bullet embedded in the heart since 1917 (see text)

STAB WOUNDS OF THE HEART

Direct injury to the heart in civil life is usually due to single or multiple stab wounds, the majority of which penetrate the right ventricle The clinical, physiological, radiological, and electrocardiographic features of cases which have survived long enough to receive medical aid have been chiefly those of hæmopericardium (Wood, 1937) Death from hæmorrhage into the pleural cavity or from cardiac tamponade may be prevented by timely surgical repair.

Even when patients appear to be holding their own, it is probably wise to evacuate the blood clot and to repair and sterilise the wound as soon as possible, for hæmorrhage may continue or recur, and serious cardiac tamponade develops in most cases Moreover, if tamponade is unrelieved too long, acute coronary insufficiency may seriously impair the function of the myocardium, and when it is finally relieved, death may result from acute heart failure The development of a bulge on the left border of the heart, simulating the appearances of ventricular aneurysm, should not deter the surgeon, for this is likely to prove no more than a localised pericardial hæmatoma (fig. 20 04)

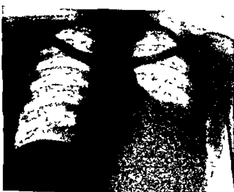


Fig. 20 04—Localised pericardial hæmatoma superficially resembling a cardiac aneurysm

EFFECTS OF INDIRECT INJURY

Indirect injury to the heart may be caused by crushes, blows, falls or blast. The effects include sudden death from ventricular fibrillation or standstill, rupture of the aorta, rupture of one or more chambers of the heart, rupture of the aortic or mitral valve, hæmopericardium, myocardial bruising, auricular fibrillation and heart block Coronary occlusion and subsequent angina pectoris or cardiac infarction may also occur, but their relationship to trauma is less well understood

SUDDEN DEATH

A heavy blow to the region covering the heart may cause sudden death from ventricular fibrillation or cardiac rupture, both naturally and experimentally in dogs (Bright and Beck, 1935)

There have been numerous instances of sudden death resulting from relatively minor trauma of a kind quite incapable of damaging the heart The catastrophe is then ascribed to ventricular fibrillation induced by neurogenic shock Sudden immersion in icy water may act in this way, extreme fright, a blow over the heart insufficient to cause material damage. Two factors seem important in these instances. a certain diathesis which used to be called status lymphaticus, but which is probably more related to suprarenal function, and a ventricle prone to fibrillation, as in elderly subjects, or in those with subclinical coronary artery disease. This type of death is similar to that which may be caused by a small pulmonary embolism in experiments in dogs the size of the embolism being quite insufficient to embarrass the circulation, and death being preventable by atropine The mechanism is probably a vagal reflex. It is possible that ventricular standstill may be responsible, rather than ventricular fibrillation, but experiments favour the latter

Rupture of the aorta is more likely to occur from a fall, especially if there is congenital hypoplasia as in many cases of coarctation Hæmorrhage is usually into the pleural cavity or pericardium.

RUPTURE OF THE HEART

Rupture of one or more chambers of the heart following trauma is not always immediate, nor does it always cause sudden death A myocardial bruise may result in cardiac aneurysm or delayed rupture, usually during the second week, as described by Bright and Beck. These authors collected over 150 cases of traumatic rupture of the heart from the literature, and found the incidence of the various chambers involved to be as follows:

Left ventricle . .	37
Right ventricle . .	31
Left auricle . . .	30
Right auricle	36

More than one chamber	. .	13
Interventricular septum	. .	11
Interauricular septum	.	1

It will be appreciated that this distribution is very different from that seen with spontaneous rupture secondary to cardiac infarction, when the left ventricle is nearly always responsible.

The latent interval was also studied by Warburg (1938) It occurred in 15 our of 51 cases proved at necropsy. A small tear may behave similarly to a direct penetrating wound that causes delayed death from hæmopericardium, usually within a few days A bruise may rupture at any time within six weeks (Barber, 1938), or occasionally after a longer interval Cardiac aneurysm resulting from a bruise may rupture years afterwards (Joachim and Mays, 1927).

During the quiescent phase the patient may seem relatively well, any discomfort being attributed to the bruise on the chest, and he may continue his normal activities, including sport (Priest, 1939) In other cases symptoms may result from hæmopericardium or from any of the other effects to be described presently.

Diagnosis. If the patient is seen alive after cardiac rupture, the signs and symptoms are those of hæmorrhage into the pericardium or pleural cavity The combination of collapse, rapid thready pulse, and a high jugular venous pressure from cardiac tamponade, is very suggestive if discovered within a month of injury. There may be no evidence of external damage to the chest wall, and the history of the accident may not be mentioned, for it may not appear to be connected with the illness. If the possibility of previous trauma is considered, the diagnosis is usually obvious

Treatment. Immediate surgical repair is the only hope of saving life.

HÆMOPERICARDIUM

Symptoms and signs of pericarditis with or without hæmopericardium (page 355) are relatively common after indirect cardiac trauma, particularly perhaps after blast injury They provide useful evidence of cardiac damage, but do not necessarily indicate its nature Surgical interference is only warranted if there is tamponade, which usually signifies cardiac rupture or serious coronary hæmorrhage Many cases have recovered spontaneously (Smith and McKeown, 1939)

MYOCARDIAL BRUISING

Crushing of the chest, direct blows over the heart, and blast may all cause myocardial contusion, the clinical picture resembling that of myocardial infarction, including the characteristic electrocardiographic changes, or heart failure without pain (Barber, 1940; Barber and Osborn, 1941)

It is of considerable interest and medico-legal importance that following a direct blow in the præcordial region, electrocardiographic changes may

occur which are indistinguishable from posterior myocardial infarction (Anderson, 1940). Whilst it is possible that this represents remote contusion, it is perhaps more likely that an anterior lesion may occlude the right coronary artery This kind of effect will be considered more fully later.

The chief danger of myocardial contusion is delayed rupture, as previously described

Treatment consists of rest in bed for six weeks, semi-starvation, a low sodium intake, mersalyl if necessary, sedatives, and avoidance of digitalis.

RUPTURED AORTIC CUSP

Indirect trauma sometimes ruptures an aortic cusp. There may or may not be underlying aortic valve disease, congenital or acquired. The lesion results in the abrupt development of aortic incompetence, which throws a heavy burden upon an unprepared left ventricle, so that failure of that chamber is likely to ensue

The diagnosis is suggested by the sudden onset of orthopnœa, paroxysmal cardiac dyspnœa, or pulmonary œdema, following a serious fall or other violent accident, and is confirmed by the discovery of a loud, harsh, sometimes musical, aortic diastolic murmur, often accompanied by a thrill, especially if the valve was known to have been normal previously.

The prognosis may be good if the patient survives the immediate insult, but death from heart failure within six weeks is a grave risk (Barber, 1938, 1944) Treatment consists of six weeks' rest in bed in order to allow time for adequate compensation, and may have to be directed towards combating left ventricular failure It must be understood that a degree of aortic incompetence which would be well tolerated and consistent with years of active life if it had developed slowly, may cause death from acute heart failure when it occurs abruptly; just as acute hypertension may cause left ventricular failure and pulmonary œdema, whereas much higher pressures may be tolerated when developing slowly in benign hypertension

TRAUMATIC MITRAL INCOMPETENCE

A severe fall, or sudden blow over the heart, or other violent accident may occasionally rupture chordæ tendineæ or tear one of the mitral cusps, particularly if already diseased. The lesion is rare, but there are many well authenticated instances (Barber and Osborn, 1937) A clinical diagnosis [illegible] -resent [illegible] when [illegible] nce of previous rheumatic valve disease, and if confirmatory signs of organic mitral incompetence develop, e.g mitral systolic thrill, left ventricular [illegible]

later (Barber, 1938) On the other hand, the accidental discovery of symptomless mitral incompetence attributable to trauma need cause little alarm, such cases behaving like rheumatic mitral incompetence with a healthy myocardium.

HEART BLOCK

There have been a number of instances of asphyxia in which hæmorrhage has taken place around the bundle of His with resulting heart block Several cases have been seen at necropsy by the author, and a good example was observed during the 1940–1 London air raids

A woman of about 35, known to have been in previous good health, was rescued in a partly asphyxiated condition from beneath a lot of debris Examination shortly afterwards revealed not only complete heart block, but also gross signs of hemi-Parkinsonism, presumably due to hæmorrhage into the bundle of His and into the substantia nigra She declared that she had received no severe blow on her chest, nor significant crush, but had been partly asphyxiated by dust for about one hour

Heart block may also result from a blow over the heart or from a fall on the chest (Coffen, 1930, Warburg, 1938), and has been so produced experimentally in dogs (Kissane, 1937) Hæmorrhage into the conducting system is presumably responsible The lesion may be transient or permanent, the prognosis depending on the presence or absence of Stokes-Adams fits, and upon the rate of the idioventricular pace-maker; but on the whole it is fairly good, provided there is no more serious injury, and provided the heart muscle is sound

AURICULAR FIBRILLATION (OR FLUTTER)

Several cases of auricular fibrillation caused or precipitated by blows have been reported (Kahn and Kahn, 1928), particularly in the elderly (Barber, 1938) Bramwell (1934) records a case in which auricular fibrillation was probably initiated by a head injury, and Hay and Jones (1927) describe one due to electric shock

The mechanism whereby head injury may cause auricular fibrillation is particularly interesting, though still obscure There is reason to believe that parasympathetic activity may be culpable Thus, digitalis, which stimulates the vagus, may cause auricular fibrillation, and there is a form of sinus bradycardia due to vagal influence which is associated with paroxysms of flutter or fibrillation In experiments on certain animals, fibrillation may be induced by vagal stimulation Not only head injury, but also meningitis, Ménière's syndrome, and probably other intracranial disturbances may excite this rhythm change

CARDIAC INFARCTION AND ANGINA PECTORIS

As already described, myocardial contusion may give rise to clinical and electrocardiographic features similar to those of myocardial infarction, and

may also result in cardiac rupture or aneurysm. There appears to be a closer relationship, however, between trauma and ischæmic effects. For example, an anterior injury to the chest may cause a posterior left ventricular lesion clinically indistinguishable from a cardiac infarct, and classical angina pectoris may develop for the first time immediately after trauma (Campbell, 1939). Moreover, the subsequent course of these cases may be that of idiopathic ischæmic heart disease. It is possible that blows, crush injuries, and blast may injure the anterior coronary vessels, either by causing subintimal hæmorrhage in an atherosclerotic artery, or more directly, and thus cause acute coronary occlusion or secondary thrombosis. After such an event subsequent angina pectoris would be readily understood Great care must be taken in diagnosing traumatic angina however, for many persistent chest pains following injury represent a compensation neurosis

Treatment consists of three to six weeks' rest in bed, followed by one to three months' convalescence, to allow time for the development of adequate collateral vascularisation The prognosis depends upon the degree of underlying coronary disease, as well as upon the amount of damage inflicted. On the whole it is not dissimilar to that in ischæmic heart disease in general.

MEDICO-LEGAL ASPECTS

Employees are entitled to compensation if it can be shown that trauma has initiated or aggravated a cardiovascular disability. Even a case of syphilitic aneurysm that ruptures during the course of work receives compensation Patients with established heart disease may deteriorate after an accident, and this aggravation is equally compensated. The benefit of doubt is always given to the patient, and in a court of Law or a tribunal it is difficult to convince a judge or president that trauma has not adversely affected the cardiovascular system. Yet a firm stand must be taken over the development of cardiac neurosis. Left inframammary pain is especially liable to become persistent and intractable if linked to the idea of compensation, and the physician must be prepared to make a categorical statement to the effect that this is not organic and is not due to the accident· that its origin lies in the mind and in the emotions, and its growth runs parallel with the conscious or subconscious desire for gain.

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CHAPTER XXI

CARDIOVASCULAR DISTURBANCES ASSOCIATED WITH PSYCHIATRIC STATES

THE cardiovascular system may be profoundly influenced by psychological or psychiatric states through the medium of the autonomic nervous system. The stimulus is emotional, and appears to act on the central vegetative nuclei in the region of the hypothalamus We are all familiar with the uncomfortable thudding of our hearts during moments of fear, and most of us have witnessed a fainting attack provoked by the sight of something which is at once queer and frightening The physiological basis for such phenomena is relatively simple, sympathetic or adrenergic activity may cause palpitations by accelerating the pulse, elevating the blood pressure, and strengthening the heart beat, parasympathetic or cholinergic activity may induce syncope by retarding the pulse, lowering the blood pressure, and weakening the heart beat

Cardiovascular upsets of this kind, sufficient to bring the patient to seek medical advice, almost invariably indicate psychiatric disorder, for the effects of emotion within the limits of common physiological experience are too transient and too familiar to disturb a normal individual Moreover, in psychiatric states such symptoms may be persistent or may be provoked too readily The syndrome so produced has been called "soldier's heart", irritable heart, disordered action of the heart (D A H.), cardiac neurosis, effort syndrome, autonomic imbalance, neurocirculatory asthenia, etc Such terms should be discarded in favour of the correct psychiatric diagnosis, but the words "effort intolerance" may be added with advantage, preferably in brackets, when clinically important Historically one may speak of Da Costa's syndrome to cover all previous nomenclature (Wood, 1941)

The syndrome is characterised by a group of symptoms which unduly limit the subject's capacity for effort, or which upset his peace of mind at rest, by a number of signs which depend upon disturbance of the autonomic nervous system, and by an underlying psychiatric disorder The cardinal symptoms are breathlessness (93 per cent), palpitations (89 per cent), fatigue (88 per cent), left inframmary pain (78 per cent), and dizziness (78 per cent) or syncope (35 per cent) The cardinal signs are those of functional disturbance of the respiratory, vasomotor, sudomotor, and muscular systems The psychiatric disorder is commonly an anxiety state, but may be almost anything with high emotional content, including the psychoses

It should be understood that there is no essential difference between "effort syndrome" and "cardiac neurosis", they are merely clothed differ-

ently, the former in battle dress, the latter in artificial silk. In civil life the condition accounts for 10 to 15 per cent of all cases referred to cardiovascular clinics; it is common in children, and occurs more often in women than in men, the ratio being 3 : 2. It has a preference for the emotional races, especially the Jews and the Italians. In the first world war there were some 60,000 "effort syndrome" casualties in the British forces; in the second a more enlightened view was taken, the majority of these cases receiving appropriate psychiatric labels and management

CLINICAL FEATURES

The cardinal symptoms and signs have already been mentioned; they will now be discussed in more detail

Breathlessness. These patients experience a true sensation of breathlessness in circumstances that would not affect a normal person. It is not only a question of breathlessness on effort, but patients will say they are unable to obtain a satisfying breath, or that they feel a sense of suffocation, and this is confirmed objectively by frequent deep sighs. Sometimes they complain of attacks of noctural dyspnœa which may be confused with bronchial asthma or with paroxysmal cardiac dyspnœa; careful questioning, however, should reveal their psychosomatic nature, especially by probing the precipitating anxiety dream, and by unmasking the associated panic state. Further evidence of functional respiratory disorder may be obtained by noting hurried, irregular, and shallow breathing A simple and illuminating test is forced hyperventilation. The patient is asked to breathe deeply and rapidly for one minute. A normal individual experiences dizziness, and sometimes slight tingling of the fingers and toes. When told to stop he passes into a state of apnœa lasting about 20 seconds. The psychoneurotic, especially the hysteric, dramatises his subjective sensations, and when told to desist usually continues forced breathing, explaining later that he felt breathless Since dizziness and tingling of the extremities are due to vasoconstriction induced by carbon dioxide washout, it is clear that such psychoneurotics experience breathlessness when the carbon dioxide content of the arterial blood is so low as to cause apnœa in controls. The respiratory stimulus must therefore come from higher centres. The maxi- [illegible] Normal subjects have no [illegible] ids; but patients with [illegible] o per cent of them in less than 10 seconds, moreover, in contrast to controls, they show little distress when they reach the breaking-point

Palpitations. Cardiac overaction resulting from emotional stimulation plays an important rôle in the induction of cardiac neurosis. It is a common psychiatric event for some intangible fear to become linked to something more easily understood and remote from the real difficulty. For example, a psychoneurotic with a morbid fear of heights may develop palpitations

when ordered to climb a ladder. If the idea that palpitations may denote some disorder of the heart occurs to him, he at once embraces the possibility, and proceeds to advance the theory in all seriousness, for it disguises his true fear which might be thought shameful, and protects him from the danger. Although a successful defence mechanism in these two respects, the manœuvre is baneful because it provokes a new fear: that of heart disease and sudden death; this new fear aggravates the palpitations, and so closes a vicious circle.

The palpitations of anxiety states are associated with sinus tachycardia, elevation of the blood pressure, increase in cardiac output, and probably with strengthening of the heart beat. These features are due essentially to emotional stimulation of a normal adrenergic system.

Fatigue. Patients often complain that they do not feel refreshed when they wake in the morning; that their sleep has been of no benefit to them. They also feel tired and listless during the day, and are unduly fatigued by effort. The symptom is usually attributed to anxiety dreams and to emotional conflicts.

Left inframmary pain. Psychosomatic pain is usually situated in the left inframmary region, but may be higher, lower, more central or more lateral; it may radiate down the left arm. It is commonly described as aching or as sharp and stabbing in quality; but occasionally it is constricting or cramp-like. Although pain may occur during effort, it is more frequent afterwards, it is also common at night and may prevent the patient sleeping on the left side; sometimes it is capricious and bears no relationship to any known factor. Sharp twinges are momentary, and acute stitch-like pain may last several minutes, but the classical ache usually continues for hours. It thus usually differs from angina pectoris in its eccentric site, in its quality, in its relationship to effort, and in its duration; i.e. in every important respect. Occasionally, however, as may be inferred from the description given above, psychosomatic pain may be situated near the left border of the sternum, referred to the left arm, constricting in quality, and measured in minutes. In such cases it may well be misinterpreted. There is usually some odd remark, however, or something in the patient's manner, which should warn the physician and encourage him to launch a critical cross-examination. The precise history of angina pectoris will not be shaken by this, but that of an anxiety state alters and becomes more complicated and confused when elaborated.

Left inframmary pain is important because it seems to convince the patient that his heart is diseased, and it is not unnatural that he should think thus of a pain arising so close to it. In the psychoneurotic this creates a morbid fear of death and catastrophe, and so closes another vicious circle.

The exact mechanism of the pain is obscure. It is immediately abolished by the intramuscular injection of 2 ml. of novocaine at the site of maximum intensity or tenderness. Cutaneous or subcutaneous anæsthesia has no

effect This indicates that it is not referred, but arises locally in muscle or fascia, and suggests that it is related to "fibrositis" and low back pain It may be initiated by *fatigue or strain of respiratory muscles in cases with* respiratory neurosis, by strain of certain muscular attachments involved in such actions as cranking an engine or lifting a heavy weight, by incessant minimum trauma from the light hammer-blows of an overacting heart, or by faulty posture. It is exaggerated and perpetuated by the belief that it arises in the heart.

Dizziness. Dizziness means momentary faintness, transient unsteadiness, "light-headedness", or a "far away feeling". It does not refer to spinning as in vertigo. It may occur on sudden movement of the head, on standing up abruptly, or during effort It is readily reproduced by hyperventilation, when it is attributed to cerebral vasoconstriction. Orthostatic dizziness is related to orthostatic hypotension, and is due to inadequate circulatory adjustments on assuming the erect posture. It is probable that other forms of dizziness are also due to diminished cerebral blood flow induced by *autonomic disturbance* *Transient loss of consciousness due to temporary* failure of the cerebral circulation occurs at one time or another in 20 to 30 per cent of these cases.

Sweating. Sweating is a helpful diagnostic feature, because in the majority of instances it is confined to the axillæ, to the palms of the hands, and to the soles of the feet These are emotional sweat areas. Thermal sweating, and that induced by cholinergic drugs, have a different distribution, being much more widespread Sweating associated with effort may begin emotionally, but is soon thermal Thyrotoxic sweating is also thermal. The hands are the best single guide: if sweating is confined to the palms, the stimulus is emotional, if the backs of the hands are also involved other causes should be considered Undue sweating is mentioned or admitted by 80 per cent of these cases, and is seen objectively in about two-thirds.

Headache. Headache is a common complaint (72 per cent), and is either vague or throbbing. In assessing the reality of the physical basis of the throbbing type it is helpful to ask the patient to count the throb *aloud*, or better, to tap out the rhythm digitally while the observer checks this against the pulse rate: in true vascular headache they must coincide; in hysteria they do not. Unilateral carotid compression is also useful, for it abolishes vascular headache on the same side, but it either aggravates or has no effect upon hysterical pain. Throbbing vascular headache may be induced by the intravenous injection of 1 mg. of histamine, or by trinitrin or amyl nitrite in some cases It is closely associated with exaggerated pulsation *of the* cerebral arteries (Pickering, 1939). It is seen clinically not only in the anxiety states, but also in fevers, and in acute alcoholism It occurs spontaneously in migraine. Improvement depends upon better *autonomic* regulation, which in turn depends upon successful treatment of the underlying anxiety state.



Fig 21 01—Classical facies, build and posture of a case of Da Costa's syndrome Painted by Ian Tillard (life-size portrait in the museum of the Post-Graduate Medical School of London)

PHYSICAL SIGNS

Signs of autonomic disturbance serve to check the validity of psychosomatic symptoms Most have already been mentioned, but they will be recapitulated and grouped here for convenience.

General

- Tense, dejected, or diffident manner
- Dull, weak, or listless, facies
- Soft, quiet, timid voice

Cardiovascular

- Tachycardia (30 per cent)
- Overaction of the heart (44 per cent)
- Blood pressure in the region of 150/90 mm Hg (27 per cent above)
- Deceleration time over 2 minutes in effort tolerance test (33 per cent)
- Acrocyanosis (44 per cent)
- Flushes (36 per cent)

Respiratory

- Frequent deep sighs (32 per cent)
- Rapid, irregular, or shallow breathing, occasionally hyperventilation (21 per cent)
- Inability to hold the breath for 30 seconds (76 per cent)
- Dyspnœa instead of apnœa after forced breathing

Sudomotor

- Visible sweat on the palms of the hands (67 per cent)
- Sweat trickling from the axillæ (35 per cent)

Skeletal and Muscular

- Tremor of fingers usually coarse, irregular, and inconstant (26 per cent)
- Shakiness of voice and limbs
- Asthenic posture or poor physical development (41 per cent)
- Tenderness in area of left inframmary pain

A life-sized portrait of one of these patients (fig. 21.01) hangs in the library of the Postgraduate Medical School of London and surpasses any description. The effort-tolerance test consists of stepping on and off a chair ten times, and counting the pulse rate before, immediately after, and subsequently at minute intervals until the resting speed is regained. The deceleration time is abnormal (over 2 minutes) in 33 per cent of these patients

Physical signs of autonomic disturbance are helpful in distinguishing the malingerer, and in assessing the severity of the case. About 90 per cent of normal young adults do not show more than one of these signs, and 50 per cent show none.

PSYCHIATRIC ASPECTS

Although the syndrome described may occur in any psychiatric state with high emotional tone, it is usually associated with an anxiety state In many there are hysterical features, and a large number show reactive depression.

The family history is tainted with psychoneurosis in 50 to 60 per cent, compared with 5 to 10 per cent in controls with or without organic heart disease. About 66 per cent describe neurotic traits in childhood morbid fears, especially of the dark, of heights, of water, or of animals, are frequent, bed-wetting, stammering, tics, nightmares, sleep walking, and undue delicacy of health are common. They are timid children, far too dependent upon maternal protection. At school, kindly doctors and soft mothers protect them from the hazards of football, swimming, and the gymnasium

It is probable that predisposition to psychoneurosis is mainly hereditary. but early environmental factors, such as domestic strife, insecurity, suppression, and maternal coddling, play their part

There are many factors which may operate to bring about the adult syndrome, and in any particular case one should never be satisfied with the discovery of only one or two. It is fruitful to search for evidence of predisposition, for a state of mind recently prepared for the development of psychoneurosis by external or by endogenous factors, for precipitating agents, for the growth of vicious circles, and for motives for gain that aggravate and perpetuate the syndrome Proper assessment, management, and prognosis, are impossible if any vital link is overlooked

Hereditary and environmental predisposition have already been discussed The mind is especially prepared for the development of psychoneurosis when in a state of confusion and unreality Head injuries effect this, certain acute fevers are often responsible, especially rheumatic fever, influenza, meningitis, and diphtheria; long hours of work in unpleasant and unhappy surroundings may be to blame

Precipitating factors are often multiple It is as if one or two could be coped with, but when several occur one on top of the other, mental equilibrium disintegrates They are usually closely linked with fear in some form or another. The most obvious example is active service, hence the high incidence of the disorder in war Fear of football, and fear of swimming are common in childhood, and may precipitate anxiety at school The fear of being unsuccessful, of not being able to shoulder responsibility, is a common cause of breakdown in civil life Insecurity or fear of the future is also common The adoption of a line of action contrary to established social custom may cause an anxiety state due to fear of discovery and public criticism Difficult personal relationships, especially between husband and wife, are often responsible Sex difficulties are important, but should not be over-emphasised Financial worry, unemployment, and fear of disease play their part To a timid sensitive character, the fear of

being found out, of being thought a coward, of being proved inadequate, of seeming a fool—and so of losing cast, is a very real and powerful emotional stimulus

The development of vicious circular patterns is interesting. In this particular syndrome most vicious circles have a common basis, and revolve round the fear of heart disease and sudden death. The combination of breathlessness, dizziness or syncope, fatigue, and especially palpitations and left inframammary pain, provides convincing evidence of heart disease to the lay mind All these symptoms, which are psychosomatic in mechanism, may be produced by simple anxiety, and may disappear rapidly as soon as the anxiety is resolved. But if the patient takes the fatal step and believes that they are due to heart disease, a vicious circle is at once established, for a new and greater fear develops: that of sudden death at any moment This constant anxiety, operating consciously or subconsciously every second of the day and night, increases the severity of the psychosomatic symptoms Under these circumstances the syndrome is maintained long after resolution of the original anxiety Superimposed upon this pattern or independent of it, there develop various and often complicated conditioned reflexes, until finally distressing autonomic reactions are so ingrained and so divorced from conscious thought as to be practically ineradicable Correct medical interpretation of early psychosomatic symptoms is of the utmost importance in the prevention of these pernicious grooves The doctor who misinterprets a boy's fear of water and accepts the pallor and palpitations as signs of heart disease, who mistakes left infram[illegible]
m[illegible]
a[illegible]
is also responsible for turning his patient into a chronic and incurable psychoneurotic. Even so, it may be comforting to know that medical blunders of this kind will influence only 10 per cent of apparently normal individuals, the great majority adversely affected showing evidence of predisposition

Finally, there is the motive for gain This is seen in compensation neurosis, and in war it is obvious at every medical board. The inadequate personality of so many of these patients capitalises the symptoms What timid man, indifferent to higher ideals, will face the dangers of battle, when the very symptoms of his fear offer him protection?

DIFFERENTIAL DIAGNOSIS

The characteristic symptoms and signs associated with psychiatric disorder usually make the diagnosis easy. The physical features have been stressed because the psychiatric state may not be obvious until the mind has been deeply probed. This is well shown by comparing the conclusions drawn at the special investigation centres for "effort syndrome" during the

first two world wars: at Hampstead in world war I, where little attention was paid to psychiatry, not more than 10 per cent were considered psychoneurotic; at Mill Hill in world war II, a psychiatric basis was proved in 94 per cent. The diagnosis should be positive, not dependent upon a process of exclusion, it may stand even when organic disease is also found, especially mild rheumatic heart disease, benign hypertension, and chronic bronchitis.

Thyrotoxicosis may present difficulty to the inexperienced. The common mistake is to diagnose an anxiety state as thyrotoxicosis, rarely the reverse. The difference is fully considered on page 481 and 485 Particular attention should be paid to the attitude and behaviour of the patient, to the expression of the eyes, to the colour and temperature of the hands, to the distribution of sweating, to the diastolic blood pressure, and to the appetite.

In children, active rheumatic carditis may cause confusion, vague muscle pains being mistaken for joint pains, and tics for chorea

Attacks of violent palpitations in anxiety states are sometimes confused with paroxysmal tachycardia. Accurate history taking and observation of an induced attack should prevent error The special points of difference are given on page 133

The distinction between left inframammary pain and angina pectoris has already been considered, but real difficulty may arise. In both, the diagnosis depends largely upon the history, and cannot be proved or disproved by the demonstration of psychoneurosis on the one hand, or of organic heart disease on the other. The matter is further complicated by the adverse effect of anxiety upon ischæmic heart disease, for it may be so important a factor that its satisfactory resolution may temporarily relieve angina pectoris. Occasionally the diagnosis remains doubtful until determined by the future course

The physician should be on his guard against pulmonary tuberculosis, chronic undulant fever, juvenile spondylitis, spontaneous hypoglycæmia, subacute bacterial endocarditis, deficiency of the vitamin B group, and certain endocrine disorders—especially the menopause Anæmia should be more obvious. When the symptoms first arise during convalescence, simple reassurance should be given and the final diagnosis deferred until it is clear that rapid recovery has or has not taken place

TREATMENT

Treatment is never easy, and is the more difficult the longer it is delayed Failure is certain if any essential factor in the development of the syndrome is overlooked, so that a great deal of time must be spent on these patients. Simple reassurance and some superficial explanation are quite inadequate

First, the patient must feel that at last he has met a doctor who thoroughly understands his case; secondly, a complete physical examination, supported

by fluoroscopy and an electrocardiogram, is necessary, so that he will respect unconditional reassurance. Adequate explanation must follow, and will vary according to the chief symptoms. The object is to convince the patient that the symptoms are emotionally produced. One may point out how sudden fear causes palpitations, sweating, alteration of breathing, and sometimes a fainting attack He will agree with this, but may object that he feels no such fear. One should then explain that great fear acting for a few seconds may be more than equalled by a tiny remote fear acting over weeks, months, or years; a state called anxiety. This step is difficult, but the point must be carried Correct interpretation of anxiety dreams is of value in demonstrating the power of subconscious emotion Enlightenment and conviction may come suddenly if psychosomatic disturbance on some particular occasion or under certain specific circumstances can be explained in the light of emotional experience

For example, a patient at Mill Hill gave a history of a morbid fear of fireworks in his boyhood, conditioned by London air raids in his infancy. Otherwise he was fit and strong He was called up in September 1939, was sent to France, and remained well until told one day to unload an ammunition lorry. On handling the shells he became curiously panic stricken, developed gross psychosomatic symptoms, and mis-interpreted them, thinking they meant heart disease. A vicious circle was initiated, he reported sick, and finally arrived at a base hospital with an established "effort syndrome" When the link between his fear of [illegible]

all other explosives was unabated. Treatment had only been directed towards the removal of effort intolerance, by abolishing the misinterpretation and vicious circle that initiated and maintained it

As a rule, however, it is not enough to reassure and give an adequate explanation, for by the time the patient consults a physician the syndrome is usually highly complex, and conditioned reflexes are well ingrained. To cut across such reflexes and vicious circles, one may encourage the patient to come to better terms with his symptoms. He fears them because he thinks they are injurious, and may result in sudden death. He must be told they are harmless, that they can never be more than a nuisance, that he is already familiar with the worst they can do. Once he appreciates the fact that if he no longer fears his symptoms he will cease to aggravate them, the point is scored

If there is an hysterical motive for gain it must be mentioned, and then ruthlessly underlined It is remarkable what little insight these patients have, and disconcerting how little shame.

The methods so far outlined do not touch the underlying psychoneurosis, and the real treatment has yet to begin. The patient may be referred to a psychiatrist, or if the causative factors seem clear the physician may prefer to deal with them himself. There are always three things to consider: the

difficulties in which the patient is floundering, his reaction, which is based on his character and intelligence, and his attitude towards his reaction The difficulties should be taken first, sorted out, and resolved as far as possible. The help of social welfare workers may be enlisted in this respect. The *patient's reaction should be analysed, and some psychiatric skill and* knowledge are required to do this. It is often possible to show that his reaction is based on false values, ideas, or beliefs. Or one may simply explain just why he so reacts, in order to give him insight It is impossible to outline precisely just what is required, for every case is different, and needs individual treatment. If the problem has no satisfactory solution, and if the patient's reaction cannot be altered favourably, then at least he may learn to get on better terms with both Difficulties must be faced, and not hidden away in the dark recesses of the mind, highly personal matters [illegible]

Finally, the background must be assessed. With strong hereditary taints and bad early environment, the outlook is poor, and the aim should be to fit the patient into circumstances which will cause the least embarrassment This is a confession of failure. At the other extreme, if the stock is good, and if there is no evidence of predisposition, and if this is confirmed by the severity of the stress of anxiety causing the breakdown, every effort should be made to cure the patient. In other words, one should deal with the environment when the prognosis is bad, and with the patient when it is good.

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(A full bibliography is contained in these three articles)

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